

# ИЗВЕСТИЯ АКАДЕМИИ НАУК СССР СЕРИЯ ГЕОЛОГИЧЕСКАЯ

IZVESTIYA AKAD. NAUK SSSR

SERIYA GEOLOGICHESKAYA

## CONTENTS

No. 9, September

	Page
PROBLEMS OF THE GENESIS OF THE ENDOGENETIC MAGNETITE ORES OF THE TUNGUSKA SYNECLISE ON THE SIBERIAN PLATFORM, by N. V. Pavlov .....	1
THE PECULIARITIES OF THE STRUCTURE OF THE MAYTAS GRANITE MASSIF (IN THE NORTHERN PRIBALHASH AREA) AND THE DISTRIBUTION OF CERTAIN RARE ELEMENTS IN IT, by V. V. Buldakov .....	18
THE METALLOGENY OF ORE DISTRICTS, by Ye. T. Shatalov .....	28
THE FOLDED BASEMENT OF THE URALS PART OF THE WESTERN SIBERIAN SHIELD, by V. N. Sobolevskaya .....	41
THE QUATERNARY GLACIATION IN WESTERN TUVA AND THE EASTERN PART OF THE GORNY ALTAY, by N. A. Yefimtsev .....	52
BRIEF COMMUNICATIONS	
THE DEEP FAULTS ON THE BOTTOMS OF THE OCEANS by D. G. Panov .....	72
THE PROBLEM OF THE GENESIS AND THE AGE OF THE DINOSAUR STRATUM IN SOUTHEASTERN BET-PAK-DALA, by V. I. Yeliseyev .....	75
THE WINNERS IN GEOLOGY .....	79
REVIEWS AND DISCUSSIONS	
THE PETROGRAPHY OF IGNEOUS ROCKS, by V. P. Petrov .....	82
THE REMARKS ON D. O. ONTOYEV'S ARTICLE "ON THE LOCALIZATION OF NICKEL-COBALT ARSENITE ORES IN THE CARBONATE VEINS WITHIN SKARN ROCKS," by N. N. Shishkin .....	85
A. G. ALIYEV AND V. P. AKAYEV'S BOOK, "THE PETROGRAPHY OF THE JURASSIC DEPOSITS IN THE SOUTHEASTERN CAUCASUS," by G. N. Brovko .....	87

BIBLIOGRAPHY .....	
CHRONICLE .....	

# EDITORIAL COLLEGIUM

- G. D. Afanas'yev (assistant chief editor), Corresponding Member of the ASUSSR;  
     G. P. Barsanov, Doctor of Geological and Mineralogical Sciences;  
     K. A. Vlasov, Corresponding Member of the ASUSSR;
- A. D. Yershov, Candidate for Geological and Mineralogical Sciences;  
     O. D. Levitskiy, Corresponding Member of the ASUSSR;  
     S. I. Mironov, Academician;
- F. B. Chukhrov, Corresponding Member of the ASUSSR;  
     N. S. Shatskiy, Academician;
- D. I. Shcherbakov, Academician (chief editor);
- V. S. Yablokov, Candidate for Geological and Mineralogical Sciences  
     (secretary of the editorial collegium).

T-08808 Approved for printing August 25, 1958

Circulation - 4,200 copies. Order 3183.

Paper size 70 x 108-1/16. Paper 4-1/4. Printing sheets 11.65 + 2 ins. Publ. sheets

Second printing office of the USSR Academy of Sciences Publishing House.  
 Moscow, Shubinskiy per. 10

# PROBLEMS OF THE GENESIS OF THE ENDOGENETIC MAGNETITE ORES OF THE TUNGUSSKA SYNECLISE ON THE SIBERIAN PLATFORM

by

N. V. Pavlov

Iron ore deposits of the Angara-Ilim district were discovered and began to be exploited in the middle of the last century. Up to 1911, however, these ore deposits did not attract serious attention, since the reserves appeared to be very small. This opinion was based not only on resources of these deposits that had actually been found up to now, but also on the commonly accepted opinion of Russian geologists, especially the opinion: all those who had investigated these deposits associated their formation with the magmatic activity of basic eruptive rocks ("trap rocks"); up to now it has commonly been considered impossible for basic magmas to produce large accumulations of ores by thermal means, because of the small amounts of ore components (mineralizers) in them. The fact is, indeed, that with the exception of the Siberian platform no endogenetic magnetite deposits are thus far known to exist throughout all the areas with platform structure where there are extensive rocks formed of basic magmas. In spite of these commonly accepted ideas, however, as early as in 1933 S.S. Smirnov stated that "the enormous reserves of the Angara-Ilim province must be reckoned not in thousands of tons as before, but in hundreds of thousands of tons" [15]. He based this conclusion on the fact that the mineralization was locally associated with the deep-seated activity of the magmatic activity that produced basic rocks, which were rich in volatile components, and not with any given bodies of rock exposed by erosion. The presence of volatile constituents was indicated by the aureoles of pneumatolytically and hydrothermally altered host rock enclosing the deposits. The predictions made by S.S. Smirnov have turned out to be completely correct.

The genesis of the magnetite deposits of the Angara-Ilim district was discussed for a long time in geologic literature, but remained to a great degree obscure because of the lack of detailed prospecting work. More recently, the large-scale work of geologic prospecting and scientific investigation that has been done has greatly

increased our knowledge of these unique deposits, so that a full examination of the problems of their genesis may now be made.

The discovery of additional magnetite deposits within the Tungusska syncline, which occupies more than a million square kilometers of the Siberian platform, will depend to a considerable extent on the correctness of our conceptions of their genesis.

## 1. A BRIEF REVIEW OF THE IDEAS REGARDING THE GENESIS OF THE MAGNESIFEROUS MAGNETITE DEPOSITS IN THE TUNGUSSKA SYNECLISE ON THE SIBERIAN PLATFORM

The earliest concept of the conditions leading to the formation of the magnetite deposits was formulated by K.I. Bogdanovich [2], who in 1894 visited the Priangara group of deposits belonging to the former Nikolayev Works.

He assigned these deposits to the category of vein deposits formed "hydrochemically"; this was confirmed by the "ribbon-like structure of the veins, the frequent formation of botryoidal structures on the contact surfaces of individual veins, and the typical selvages." The host rocks, in his opinion, are tuffs and tuff breccias, and the formation of the deposits is associated with one of the concluding phases in the eruptive activity of the traprock magma. K.I. Bogdanovich notes the physical association of the deposits in space with the volcanic canals that follow the lines of faults. In 1895 P.K. Yavorvskiy examined the Dolonov and Krasnoyarsk deposits and determined that the ore "is a traprock, quite rich in magnetite, which takes the form of veins cutting across a fine-grained rock similar to tuff, and does not properly deserve to be called an ore." In 1917 B.N. Artemyev made some investigations in the area of the Ireysk-Kas'yanov deposits and noticed the connection of the Angara-Ilim type deposits with localities in which the Cambro-Silurian red beds have been broken through by extrusive and

aphanitic varieties of traprock; he associated their formation with faulting. The ore veins are associated with tuffs and breccias that are usually zeolitized and chloritized.

In 1920, on the orders of the Committee on Geology, S.A. Doktorovich-Grebnitskiy studied four deposits located near the Nikolayev works. He noted "the occurrence of part of the veins in sedimentary rocks" and confirmed the genetic connection of the deposits with the traprock; in addition, he considered that the source of the iron was not the traprock immediately enclosing the deposits, but the more deep-seated magma chambers that produced the traprock. The iron, in his opinion, was transported by "pneumato-hydrogenic agents" and the ores are "typically epigenetic."

It should be mentioned that S.A. Doktorovich-Grebnitskiy denied the presence of tuffaceous rock in the deposits and considered it instead to be crushed traprock.

In 1930 F.M. Gavrilov began to make a systematic geologic survey of the Angara-Ilim district; at the same time geologic exploration, prospecting and magnetic surveys were undertaken by the Institute staff under the direction of Ye. Ye. Gudkin. S.S. Smirnov, who was in the area in 1931 and 1932, touched in his articles on the genetic peculiarities of these deposits. S.S. Smirnov's main ideas on the problems of genesis are as follows [14].

"The geochemistry of the iron ores of these deposits indicates their connection with basic magmas rather than acidic." Actually, "one may speak of a considerable addition during the formation of the deposits of such elements and compounds as Fe, Ca, Mg, H<sub>2</sub>O, CO<sub>2</sub>, P(Cl, F). This list corresponds much more closely to basic magmas than to acidic. The formation of magnesioferrite testifies to their association with basic rocks." In discussing the paragenetic associations of the minerals, S.S. Smirnov notes four successive stages in their formation:

1. An early stage (pneumatolytic) -- specifically silicate; metasomatism of the host rock leads to the formation of grossularite, diopside, part of the calcite and magnetite.
2. A middle stage (thermal A) -- specifically ore; calcite, magnetite, ophiolite (serpentine), chlorite and apatite are formed; vein-like bodies containing magnetite appear.
3. A late stage (thermal B) -- specifically calcite-chlorite and calcite.
4. A very late stage (thermal C) -- specifically siliceous ("amethystine").

In 1931 in the Ilimpey River district V.S. Sobolev [16] discovered three deposits of magnesiferous magnetite. In describing the genesis of these deposits, he said that they are high-temperature formations at the boundary of the pneumatolytic phase and associated with traprock (basaltic) magma.

In 1934 N.P. Anikeyev and V.P. Zorin published a paper based on the results of geologic explorations of 1930 - 1933 around certain deposits of the Angara-Ilim district. In a monograph published in 1936 [1] N.P. Anikeyev devoted special sections to questions of: 1) the successive stages in mineral formation, 2) the nature of the mineralization, 3) the shape of the deposits and the nature of the canal that fed them, 4) the genetic association of the deposits with the traprock and 5) the overall genesis of the deposits. N.P. Anikeyev's basic ideas are cited below.

In discussing the successive stages of mineral formation, the author adopts the main features of S.A. Doktorovich-Grebnitskiy's scheme and also distinguishes four phases of mineralization: 1) granitization and pyroxenization, 2) serpentinization and calcification, 3) mineralization of ore minerals and calcification, and 4) calcification and silification.

In opposition to S.A. Doktorovich-Grebnitskiy's views, N.P. Anikeyev states that the third and fourth phases, in addition to the processes of crustification, was accompanied by metasomatism. In his scheme of the succession of mineralizing processes he includes apatite and hematite not mentioned by S.A. Doktorovich-Grebnitskiy.

As regards S.S. Smirnov's opinions, N.P. Anikeyev disputes the basis for distinguishing the first, pneumatolytic stage by saying that "the processes of granitization and pyroxenization are no different in principle from the other stages of mineralization." In his section on "The Nature of the Mineralization" points out the intensity of the mineralization process and the considerable degree of metamorphism surrounding the veins. In touching on the effect of the host-rock composition, he says that "the nature of the wall rocks plays a determining role in relation to both the types of metamorphosed rocks and the shapes of the ore bodies." In the process of mineralization, N.P. Anikeyev establishes that calcite was introduced first and iron later. "One cannot be entirely certain that the magnetism was introduced during the course of the ore-forming processes."

In his section on "The Shapes of the Deposits and the Nature of the Feeding Canal" the author says that "the veins of the Anga

lim deposits belong to the category of complex veins. The overwhelming majority of the veins has a steep ( $70^{\circ}$  to  $80^{\circ}$ ) dip."

In regard to the ore-feeding canal, he says: "Evidently there were no open fissures. . . The magmatic solutions gradually created suitable channels in places where the rock was weak or even, perhaps, in incipient fissures; these were subsequently fixed by the formation of veins." The depth of the veins will depend on the depth of the magma chamber that fed them.

After examining the question of the deposits' genetic connection with the traprock, N.P. Anikeyev concludes that "according to their chemistry, the Angara-Ilim deposits, which differ sharply from the vein deposits of granitic magmas, are a unique type of vein deposit genetically associated with basic magma" [1]. This conclusion is supported by the small part played by  $\text{SiO}_2$  and the total absence of K, Na, Li, B, etc.

N.P. Anikeyev writes: "Some of the investigators assume that the mineralizing agent in the traprock magma may have originated elsewhere, and not as a result of the differentiation of the basic magma" (B.N. Rozhkov). And farther on, without reference to the author, he states: "The suggestion has been made that the traprock magma assimilated stocks of salt associated with Cambrian deposits." In regard to the overall genesis of the deposits he says: "The initial stages in the origin of the Angara-Ilim deposits is, in our opinion, associated with the second stage of magmatic activity that produced the Siberian traprock; in the more northern areas this took the form of young cross-cutting intrusions." Moreover, N.P. Anikeyev does not describe tuffs or tuff breccias in any of the deposits, thus denying that they played any part in the formation of the deposits.

After the publication of N.P. Anikeyev's monograph more than twenty years passed, during which time only a few articles were devoted to the genesis of the Angara-Ilim deposits, and these merely touched on certain aspects of the problem.

In 1952 A.N. Zavaritskiy considered the possible origin of the oolitic ore deposits. The present author's article [11], and his article in collaboration with I.I. Chuprynina on "Magnesiferous Magnetites as Indices of the Depth of Mineralization" [12], also took up this question. In a short article by M.K. Kosygin and G.V. Roslyakov [5] on the structure and genesis of the Angara-Ilim deposits, an attempt was made to establish that "the ore bodies are connected both physically and genetically to the volcanic funnels and pipes," although the diagram given by the authors

themselves (their Fig. 1) shows that the ore veins are 800 to 1,000 m away from the pipes. In their conclusion, the authors state that the formation of the deposits "took place within the mouths of the volcanic pipes."

An article by P. Ye. Offman on "The Volcanic Pipes of the Southern Part of the Siberian Platform and the Origin of the Iron Ores Associated with them" [9] considers only certain questions regarding the geologic position of the ore segregations; the problem of their genesis is not discussed at all.

Finally, the genesis of the magnetite ores is also considered in certain unpublished papers on the individual deposits of the Angara-Ilim district (reports by A.T. Suslov, 1952; N.V. Pavlov, 1953; G.V. Roslyakov, 1954; I.N. Chirkov, 1953).

## 2. SOME QUESTIONS INVOLVED IN SOLVING THE PROBLEM OF THE GENESIS OF THE MAGNESIFEROUS MAGNETITE DEPOSITS

Both the evaluation of prospects for further exploitation and the discovery of new deposits of similar origin depend considerably on the correctness of the solution to the problem of the genesis of a given deposit. In the case of endogenetic deposits, a proper understanding of the combination of conditions governing the formation of deposits of one genetic type or another makes it possible to predict the behavior of the deposit at depth, to find the so-called "blind" ore bodies of the deposit, and to specify the basic criteria in prospecting for new deposits.

S.S. Smirnov, in considering the genesis of the Angara-Ilim deposits, noted the following four questions the answers to which would enable one to determine the conditions of their formation: 1) the source of the material making up the deposit, 2) the means by which this material was introduced, 3) the circumstances governing ore formation in the given deposit and determining the composition, the structure and texture, the occurrence of the ore bodies and their shapes and sizes, and 4) the alterations in the deposit after its formation.

S.S. Smirnov stated that "the first two questions may be answered in general only on the basis of regional geologic and mineralogic studies of the district" [14]; these have so far still not been undertaken.

During the past decade our knowledge of both the regional geology and of the magmatic activity that produced the traprock in the iron-ore districts has been greatly increased, so that it has already become possible to

make at least a partial examination of the first two questions involved in the genesis of the magnetite deposits, as posed by S.S. Smirnov.

In order to throw light on the questions of the source of the material making up the deposit and of the means by which the ores were introduced, one must examine the structural and geologic features of the magnetite deposits within the Tunguska syncline, the area containing the deposits in question and the rocks composing the traprock formations. Moreover, one must study the various phases of the igneous activity and the composition of the rocks in the traprock series. As regards the third and fourth questions posed by S.S. Smirnov, -- specifically, how was the ore material deposited in the locality and what alterations did the deposit undergo after its formation? -- the answers to these may be obtained from a detailed study of the deposits themselves, although for these questions too certain new data have been obtained which make it possible to suggest certain ideas.

### 3. THE STRUCTURE OF THE TUNGUSKA SYNCLISE AND THE IRON-ORE DISTRICTS

As a result of the systematic geologic mapping of the Siberian platform, our concepts of its structure have been broadened considerably. A diagram of the tectonic subdivisions of the Siberian platform has been drawn on a geologic map to the scale of 1:1,500,000 (by T.N. Spizharskiy, [18]). This diagram (Fig. 1) shows a number of areas of different structures, one of the greatest of which, with the specific features of its formation, is the Tunguska syncline, with an area of more than one million km<sup>2</sup>.

Up to the present time this territory has been found to contain four iron-ore districts, taking the form of magnetite deposits associated with the igneous activity that produced the traprock formations; these are the Angara-Ilim district, the Tunguska iron-ore field, and the districts of the lower reaches of the Podkamennaya Tunguska River and of the upper reaches of the Bakhta and the Ilimpey Rivers. In addition to these principal districts, magnetite formation is known to have taken place in a number of other localities of the Tunguska syncline (on the Nepa and Chunya Rivers and other places).

It is well known that the Tunguska syncline is surrounded by the following major geologic and tectonic structural areas: to the south and southeast lies the Priбайкал-Saya frontal flexure, to the east the Vilyuy and Olenek synclines and the Anabar antecline, to the north the Pritaymyr and to the west

the Priyenisey frontal flexures, and, finally, to the southwest the Angara folded zone that separates the Taseyev syncline from the Tunguska. The Tunguska syncline is separated from the above structures by zones of large tectonic faults in the basement of the Siberian platform. The above-enumerated structures of the first order that surround the Tunguska syncline are of various ages. The formation of the Tunguska syncline itself ended in the Triassic; it is made up of sedimentary deposits of the Cambrian, Ordovician, Silurian, Lower Carboniferous and Permian periods and of vulcanogenic rocks of the Triassic. All these strata are cut through by numerous intrusive bodies of traprock.

One of the characteristic features in the facies of the Tunguska syncline is the wide spread distribution of Permian continental deposits and rocks belonging to the vulcanogenic and intrusive traprock complex of the Upper Permian and Lower Triassic. In a number of places, however, these formations extend beyond the limits of the syncline.

In order to understand the structural peculiarities of the endogenetic magnetite deposits in the Tunguska syncline, it is very important to study the elements of its internal structure. According to I.I. Krasnov and V.L. Masaytis (1955), the tectonic structure of the syncline may be sketched as in Figure 2.<sup>1</sup>

Three regional zones can be clearly seen on the borders of the syncline: these involve the faults, brecciation and intensive igneous activity which, in the upper structural stages of the platform, are associated with movements *en bloc* of the Precambrian crystalline basement. These zones are the following:

The Angara-Katanga (according to T.N. Spizharskiy, the Angara-Noril'sk)<sup>2</sup> zone that borders the syncline on the southwest, the Angara-Vilyuy zone on the southeast border and the Vilyuy-Kotuy zone on the northeast edge. The last of these will not be described since iron ore has yet to be discovered there.

The Angara-Noril'sk zone runs from the villages of Bratsk and Zayarsk on the Angara River in a narrow belt northwestward to the Chadobets uplift and beyond to the Podkamennaya Tunguska district, somewhat to the west of the village of Baykit on the Podkamennaya Tunguska River. Farther on, it passes

<sup>1</sup>This discussion is confined to the two principal structural zones with which the endogenetic iron ores are associated

<sup>2</sup>The name Angara-Noril'sk is more correct.

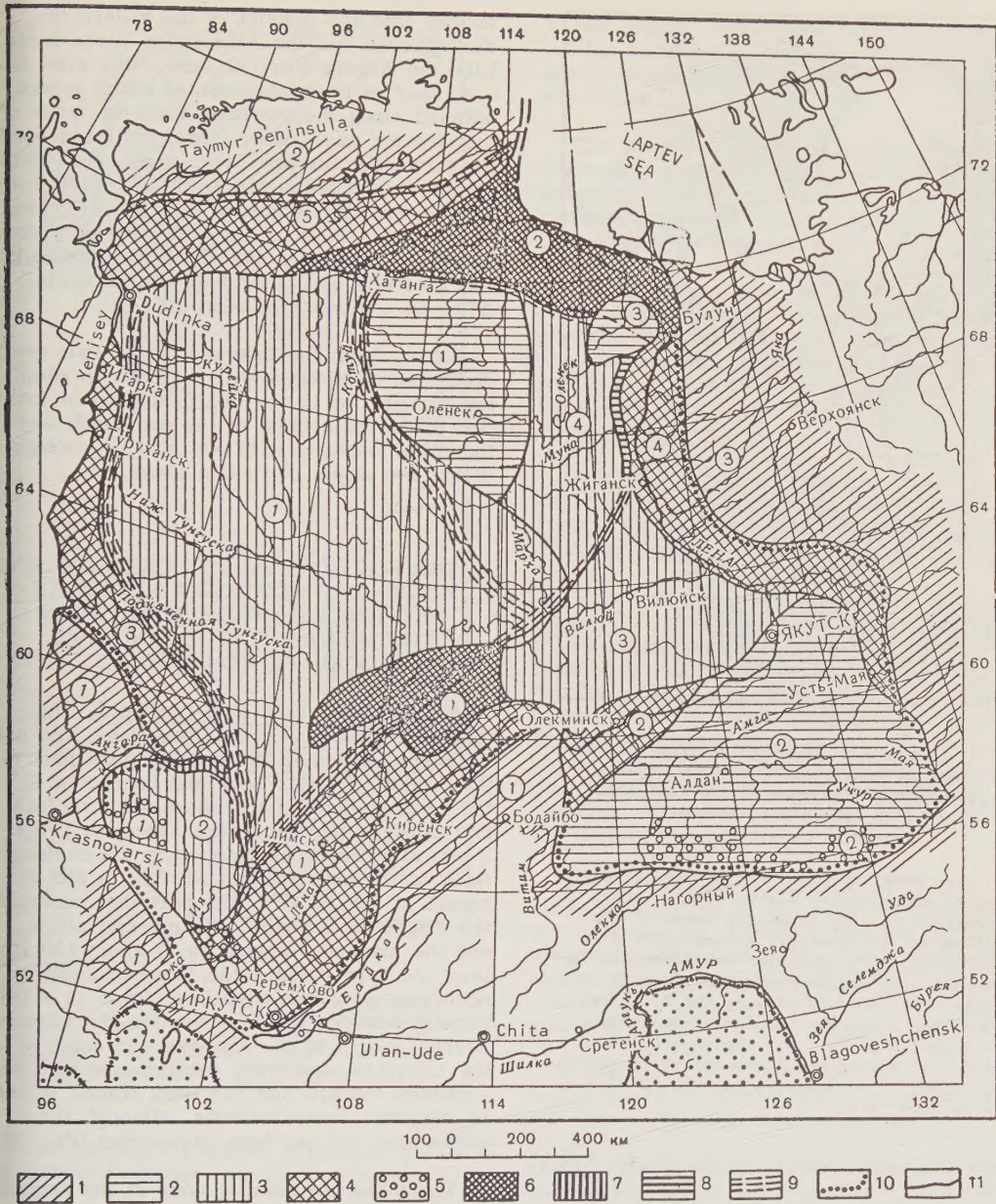


Fig. 1. Diagram of the tectonic subdivisions of the Siberian platform (compiled by T.N. Spizharskiy)

1) folded areas: 1 -- Lower Paleozoic (Saya-Baykal), 2 -- Upper Paleozoic - Lower Mesozoic (aymyr), 3 -- Mesozoic (Verkhoyansk); 2) anteclines: 1 -- Anabar, 2 -- Aldan, 3 -- Olenok up-ft; 3) synclines: 1 -- Tungusska, 2 -- Taseyev, 3 -- Vilyuy, 4 -- Olenek; 4) frontal flexures: 1 -- Pribaykal-Saya, 2 -- Berezov-Cherenden, 3 -- Priyenisey, 4 -- Priverkhoyansk, 5 -- Pritaymyr; 5) foothill flexures: 1 -- Prisaya, 2 -- Pristanov; 6) intraplateau flexures: 1 -- Angara-luy, 2 -- Lena-Khatanga; 7) Angara folded zone; 8) Prilena bank; 9) faulted zones at the edges of the Tungusska syncline; 10) main faults at the edges of the platform; 11) boundaries between different structures (the symbols set in italics are enclosed within circles on the diagram).

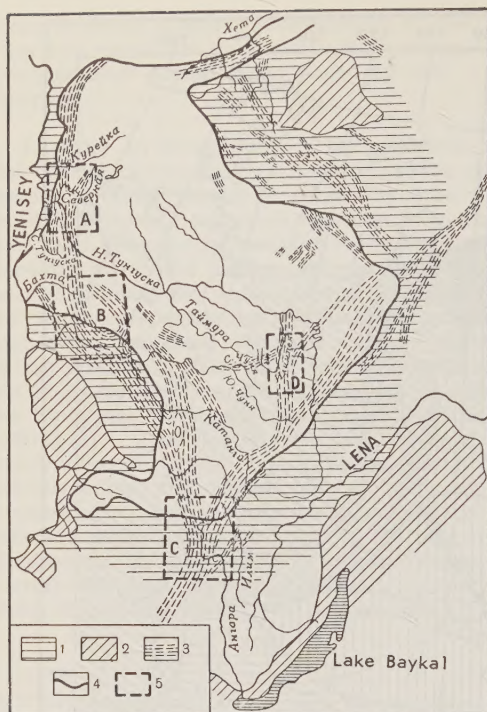


Fig. 2. Sketch-map showing the locations of the zones of faults and intensive igneous activity along the edges of the Tunguska syncline (after I.I. Krasnov and V.L. Masaytis)

1 -- areas of Lower and Middle Paleozoic deposits mantling the platform; 2 -- areas of Precambrian folding along the edges of the platform and its crystalline basement; 3 -- zones of faulting, brecciation, intensive igneous activity and magnetic anomalies; 4 -- diagrammatic contours showing the distribution of the Tunguska complex of deposits; 5 -- iron-ore areas: A -- Tunguska iron ore field, B -- Bakhta and Podkamennaya Tunguska River areas, C -- Angara-Ilim area, D -- Ilimey River area.

passes the upper reaches of the Bakhta River to the lower reaches of the Lower Tunguska River, the Kureyka River and into the Noril'sk district. The width of this zone varies from 50 to 150 km; there are branches extending from both sides. Positive magnetic anomalies have been marked in many places, along with the discovery of magnetite ore formation. The anomalies and the mineralization are both connected with the faults.

The Angara-Vilyuy zone runs from the vicinity of the village of Tulun in the north-east to the Angara River (Bratsk -- Zayarsk) and beyond to the Ilim River basin and the middle reaches of the Greater Yerema River (the left tributary on the upper reaches of the Lower Tunguska). The zone also extends

farther into the district of the village of Yerbogachen and the Akhtaranga River basin. Like the Angara-Noril'sk zone, this zone has a number of branches, one of which moves outward along the meridian from the area of the Greater and Lesser Yerema Rivers northward into the Ilimey River area. The width of this zone also varies from 50 to 150 km. The Angara-Ilim iron-ore district is located at the intersection of these two major zones so that the geologic and structural characteristics of this and other iron-ore districts differ in a number of respects.<sup>1</sup>

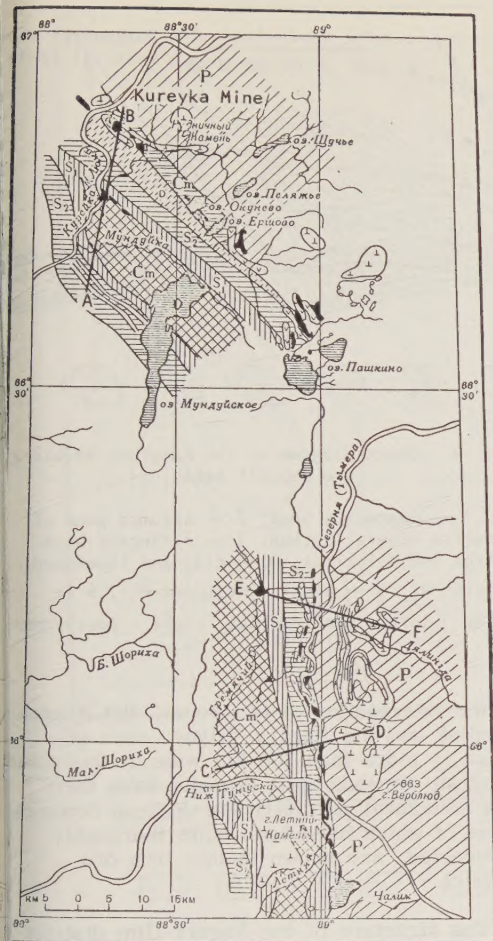
Below, from the example of the four ore districts, an attempt will be made to show the localization of the ore formation in relation to the connection of the ore fields and individual deposits with one part or another of the two zones described above.

#### 4. THE POSITIONS OF THE ORE DISTRICT WITHIN THE TUNGUSKA SYNECLISE AND THE RELATIONSHIP BETWEEN THE MINERALIZATION AND THE LOCAL TECTONIC ZONES

A. The Tunguska iron-ore field. The magnetite deposits of the Tunguska iron-ore field are located in the northwestern part of the Angara-Noril'sk zone and connected to the eastern flank of the anticlinal structure that borders the Tunguska syncline (Figs. 2 and 3). The rocks composing the eastern flank of the anticline dip NE  $35^{\circ}$  to  $65^{\circ}$  at angles of  $35^{\circ}$  to  $45^{\circ}$ . The part that contains the magnetite deposits, the mineralization and the magnetic anomalies is about 150 km long and 5 to 10 km wide. Deposits and occurrences of ore have been found in a belt running between the Kureyka and the Letnyaya Rivers. North of the Kureyka and south of the Letnyaya, however, the ore-bearing belt continues onward and has been traced further by magnetic measurements, although these areas have not yet been prospected (Fig. 3).

The main ore-bearing zone of the Kureyka-Severnaya-Letnyaya Rivers is composed of Paleozoic carbonate and terrigenous rocks. The formation of the structure of the ore-bearing zone is attributed to the end of the Permian and beginning of the Triassic. In addition to folded dislocations, the locality contains many steeply-dipping fractures --

<sup>1</sup>P. Ye. Offman in his paper on The Structure of the Central Part of the Siberian Platform presents a more complex scheme for the structure of the Tunguska syncline; in respect to the two zones with which the mineralization is associated, however, this scheme coincides with the one adopted in this article.



Geologic Sections

р. Мундуйка р. Пелаяка

В

ручей р. Северная

р. Северный наместник

Урочище Голый яр. р. Северная

Д

1 2 3 4

5 6 7 8

9

g. 3. Diagrammatic composite geologic map of the Kureyka-Severnaya-Letnaya River magnetite deposits (compiled by N.V. Pavlov from data by V.N. Yegorov and A.G. Shpil'ko)

1 -- Permian; 2 -- Carboniferous; 3 -- Devonian; 4 -- Upper Silurian, 5 -- Lower Silurian; 6 -- Cambrian; 7 -- gabbros and diabases; 8 -- gabbros and diabases altered to amphibole; 9 -- magnetic anomalies associated with ores.

ults, normal and reverse, the latest of which was formed during the Early Triassic. Within the ore-bearing zone is an extensive development of the rocks of the traprock series; they include sills intruded conformably with the bedding, dikes of amphibolized and olivine gabbro-diabases and thin veins of diorite and quartz diorite. The gabbro-diabase porphyry. The sills and dikes vary greatly in thickness, from 25 to 300 m.

These igneous bodies are located both throughout the fault zones and in the adjacent weakened zones along the bedding of the sedimentary rocks.

The amphibolized gabbro-diabases in the traprock series are older, the time of their intrusion being before the Triassic. This is confirmed by the presence of fragments of these rocks in the tuffaceous series that crops out east of the ore-bearing belt. The olivine and non-olivine gabbro-diabases were intruded in the Early Triassic. Examination of the geologic structure of individual parts of the deposits and the conditions governing the localization of the magnetite ores shows that the shapes of the ore formations fall into three groups:

a) ore bodies in the form of conformable vein-like and lenticular accumulations located in the limestones of the hanging walls of the amphibolized gabbro-diabase sills;

b) ore bodies that cut across the bedding of the sedimentary rocks and are located in the contact zones between the dikes of cataclastic and amphibolized gabbro-diabases and the limestones; these two types of geologic conditions characterizing the localization of the ores predominate in the ore-bearing zones; the peculiar feature is their physical connection with the amphibolized gabbro-diabases, which are much the earliest of the traprock bodies.

c) vein-like bodies, veins and stock-work segregations of magnetite ore within zones of tectonic fractures that cut through the conformable and cross-cutting bodies of olivine gabbro-diabases; this type of mineral localization is thus far known only at a few points along the Kureyka River.

It should be noted that the magnetite ore bodies are in weakened zones; their strikes and dips agree with those of the tectonic zones along which the magma that formed the amphibolized gabbro-diorite bodies penetrated up to the time of mineralization. This strict association of the mineralization with the hanging wall of such traprock bodies is a typical feature of the Tunguska iron-ore field in the Angara-Noril'sk zone.

B. The second iron-ore field, in which very little prospecting work has yet been done, lies in the middle of the Angara-Noril'sk zone and occupies the upper reaches of the Bakhta River and the lower and middle reaches of the Podkamennaya Tunguska River. Most probably the zone in this locality has several branches and a more complicated structure than that shown in Figure 2.

## The Bakhta-Podkamennaya Tunguska

iron-ore district is known to contain more than ten deposits and ore occurrences, although these deposits are dispersed and not associated with any one clearly defined structure, as in the preceding case. The characteristic feature of this district is the combination of relatively weak folded dislocations of Paleozoic and overlying rocks with a very large number of faults, to which the abundant traprock bodies are connected. The typical forms taken by the traprock are, besides dikes, multiple-layered sills connected by small dikes.

The bodies of traprock vary in composition, including both undifferentiated olivine gabbro-diabases (dolerites) and noticeably differentiated olivine and non-olivine gabbro-diabases.

The undifferentiated gabbro-diabases are surrounded by thin contact-metamorphic aureoles, several meters wide, which take the form of marble in the limestones and hornfels in the clay and marl rocks. No visible physical connection between the magnetite mineralization and the undifferentiated traprock is known. The differentiated gabbro-diabases contain schlieren and banded segregations of quartz and quartzless gabbro-diorite. The host rocks surrounding these bodies of traprock were subjected to extensive contact metamorphism, the thickness of the band of altered rock sometimes reaching 100 m. The contact mineralization is represented by garnet, pyroxene, epidote, chlorite, magnetite and various sulfides. The known accumulations of magnetite ores of industrial significance are associated primarily with the bodies of differentiated traprock. The mineralization is localized in zones of faulting that have been filled up by differentiated traprock, as well as in the accompanying zones of weakened rock parallel to the sedimentary bedding, along which the basic magma and hydrothermal solutions (including the ore-bearing ones) traveled at various stratigraphic levels (Figs. 4, 5).

Along the upper reaches of the Bakhta River and in the vicinity of the Krivlyaka survey mark along the Podkamennaya Tungusska River, there are known to be ore occurrences and deposits of magnetite ores that are physically closely associated with pipe-shaped bodies filled with tuffs.

The occurrence of ores here is associated with the volcanic pipes only physically; the ore bodies are associated in time with the later fault zones, as in the Angara-Ilim district. The principal Angara-Katanga zone was most likely intersected in these areas by secondary zones running in other directions.

C. The Angara-Ilim iron-ore district lies

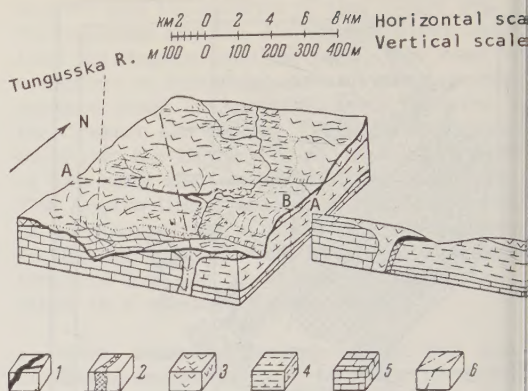


Fig. 4. Block-diagram of the Kamyshev Baykitil ore deposit area.

1 -- magnetite ores; 2 -- assumed zone of magnetite mineralization; 3 -- differentiated gabbros and dolerites; 4 -- clay and limestone deposits 0<sub>2</sub>, 5 -- algal limestones 0<sub>1</sub>, 6 -- faults: left - pre-traprock, right - post-traprock.

on the intersection of two zones, the Angara-Noril'sk and the Angara-Vilyuy, each of which is more than 100 km wide at this point. Thus all the individual deposits have their own structural peculiarities. Fifteen deposits, some of which have been quite thoroughly prospected, are known in this iron-ore district.

The structure of the Angara-Ilim district is made up of Upper Cambrian, Ordovician and Lower Silurian sediments and of tuffaceous and extrusive rocks of the Permian-Triassic traprock formation. In addition, Mesozoic (Jurassic) continental deposits have been encountered within the Angara-Vilyuy zone. This area is characterized by a generally very gentle northward dip of the sedimentary rocks, although narrow anticlinal structures are also known here. There are extensive faults with a northwestward strike; the area is also typified by volcanic pipes and intrusions of traprock in the form of sills and dikes of olivine and non-olivine gabbro-diabases of varying thicknesses.

In contrast to the iron-ore districts described above, the Angara-Ilim district along the southern and southeastern edges of the Tungus syncline was tectonically mobile for a greater length of time. This is confirmed by the finding of a Mesozoic downward flexure containing continental deposits of the Lower and Middle Jurassic.

The intersection of the two regional fault zones in the Precambrian basement and the above-mentioned higher mobility of the area

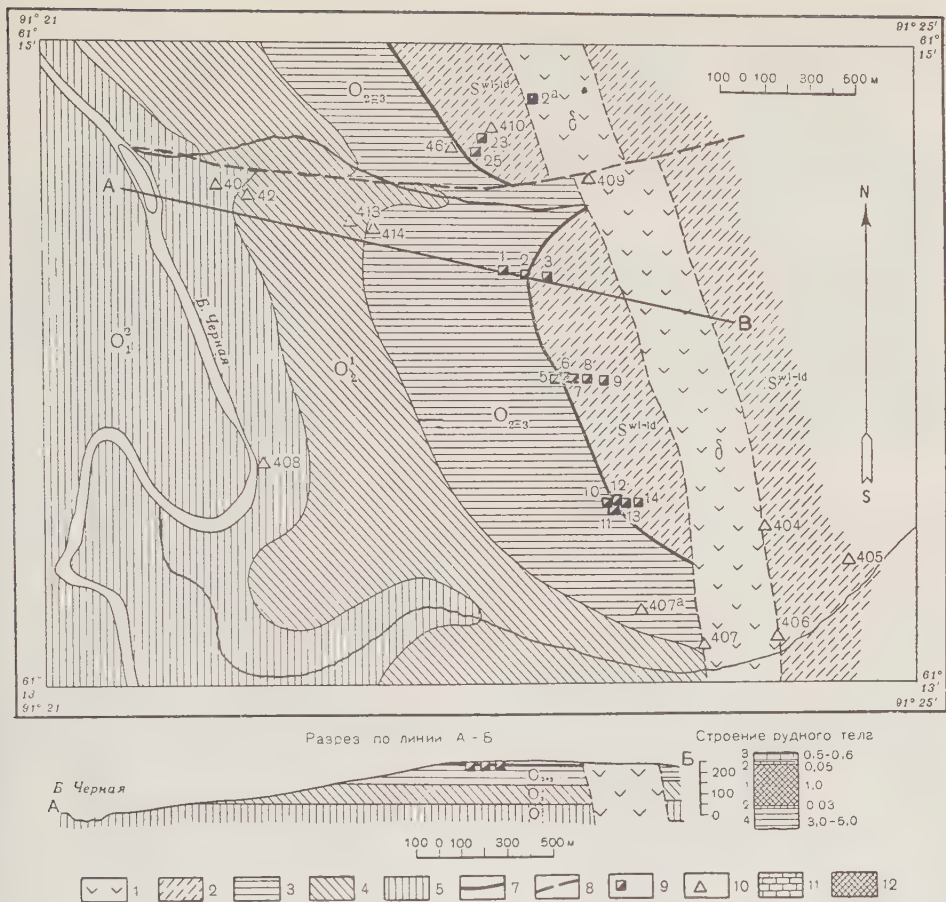


Fig. 5. Diagrammatic geologic map of the Chernaya River magnetite deposit (from data by V. P. Lisnyuk)

1 -- traprock; 2 -- Kochumdek suite, limestones; 3 -- Columar suite, aleurolites, sandstones and clay shales with limestone interbeds; 4 -- Baykitik suite, quartz sandstones; 5 -- Chunya suite, oolitic limestones, aleurolites and sandstones; 7 -- magnetite ore; 8 -- tectonic faults; 9 -- prospecting pits; 10 -- outcrops; 11 -- limestone altered to skarn and light gray limestone altered to marble, with disseminations of magnetite; 12 -- magnetite.

are the reasons for the existence of volcanic pipes and faults in the upper structural level of the platform. In addition, a close connection has been noted in most of the deposits between the volcanic pipes and zones of tectonic faults filled by traprock bodies and the magnetite segregations accompanied by broad aureoles of skarn-like rock. It must be noted, however, that the formation of the magnetite ores is not directly connected genetically with the formation of the volcanic pipes. This has been confirmed by factual data from a number of prospected deposits.

Oval or irregularly round volcanic pipes ranging in diameter from several score to 1,000 m cut across the later traprock dikes. The magnetite ore bodies, in the form of veins of various thicknesses (from several

meters to 20 m) cut both the traprock and the Paleozoic sedimentary rocks that contain the volcanic pipes. Such interrelationships between the ores and the surrounding rocks have been observed in a number of deposits -- the Kezhem, Rudnogora, Dolonov, Korshunov and others. Considerable masses of ore, however, are contained in the rocks that fill up the volcanic pipe formations (Figs. 6, 7).

These interrelationships are evidently due to the fact that the pipes, which are filled with pyroclastic material, descend to great depths and the succeeding tectonic faults have produced weakened zones and belts in these bodies which were especially favorable to the passage of the ore-bearing solutions. The trend of the ore bodies is the same as the general trend of the faults in the district,

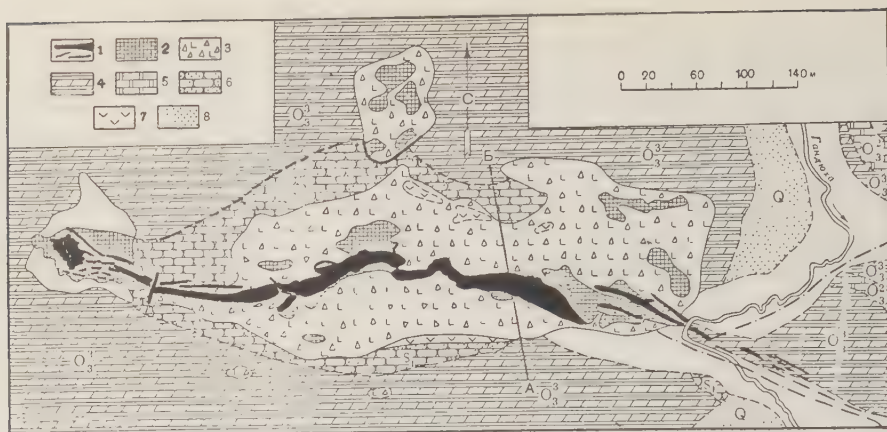


Fig. 6. Geologic map of the Rudnogorsk deposit  
(compiled by G. V. Roslyakov)

1 -- veins of magnetite; 2 -- metasomatic ores; 3 -- tufas and skarns;  
4 -- marls and argillites  $O_3^3$ , 5 -- dolomites  $O_3^2$ , 6 -- sandstones -  $S_1$ ; 7 -- traprock; 8 -- sands  $Q$ .

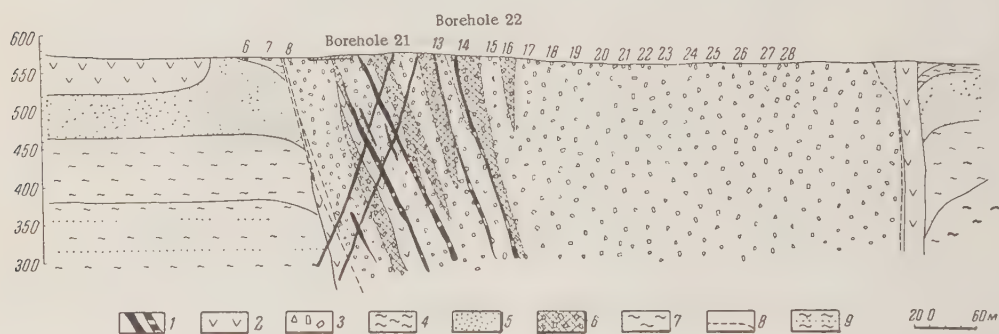


Fig. 7. Krasnoyarsk deposit (Angara-Ilim area), diagrammatic geologic section along prospecting line 5.

1 -- magnetite ore veins, a - assumed continuation at depth; 2 -- gabbro and diabase beds and veins; 3 -- tuffites and tuffaceous breccias; 4 -- argillites and marl-clays; 5 -- uneven-grained sandstones, gray and light yellow; 6 -- disseminated mineralization; 7 -- red argillites; 8 -- tectonic faults antedating the ore formation; 9 -- sand and clay rocks.

and also corresponds to the trend of the two regional zones of deep-seated faults in the crystalline basement.

D. The Ilimpey iron-ore district lies in the meridional branch that emerges from the Angara-Vilyuy regional fault zone and runs from the Yerema River area northward past the Teteya River into the Ilimpey River area. The width of this branch is more than 100 km.

This iron-ore district has thus far been little studied, and no prospecting for deposits has been done. The Ilimpey River district is known to contain up to ten points at which magnetite ore veins crop out; these

are located in an area of Permian and Triassic tuffs and tuffites whose thickness reaches 300 to 400 m. The tuffaceous rock is cut through by comparatively thin (from 5 to 50 m) dikes and sills of olivine gabbro-diabase.

The ore veins that crop out on the surface, whose thickness is from 0.5 to 0.4 m and whose visible length is up to 500 m, are associated with zones of crushed tuffs from 50 to 150 m wide. In contrast to the unshattered tuffs, which have a coarse horizontal bedding, there is no bedding in these zones and the rocks are altered and contain steeply dipping joints. The zones have different strikes, primarily northeast and northwest (Fig. 8).

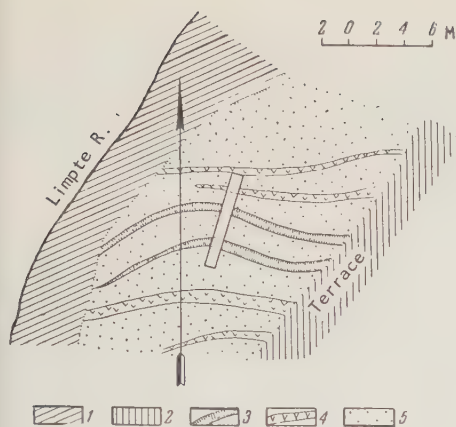


Fig. 8. Geologic map of the area near the mouth of the Bereyapchan River containing outcrops of magnetite veins.

1 -- sand deposits of the Limpte River bottom; 2 -- terrace deposits of the Limpte River; 3 -- magnetite veins; 4 -- diabase veins; 5 -- broken up and faulted tuffs and tuffaceous breccias.

A peculiarity of the ore bodies of this district is that the zones of alteration of the tuffs around the ore veins are very weak, and not characterized by high-temperature mineralization (garnets and pyroxene are rare). These deposits, moreover, are the closest to the surface of all the formations known within the Tunguska syncline, as shown by the position of the ores in the stratigraphic section. The composition of the ore-forming magnesiferous magnetite includes a high content of  $MgFe_2O_4$  molecules (up to 80 percent), whereas the accompanying gangue minerals (chlorite, calcite, quartz) are low-temperature associations.

Thus a common characteristic feature of the majority of deposits in the iron-ore districts of the Tunguska syncline is the close association of the mineralization with the faults that preceded the mineralization.

##### 5. THE SUCCESSIVE STAGES OF VULCANISM, THE COMPOSITION OF THE IGNEOUS ROCKS AND THE FORMATION OF THE MAGNESIFEROUS MAGNETITE ORES

The igneous rocks within the territory of the Tunguska syncline are associated with volcanic activity in the Late Paleozoic and Early Mesozoic.

Investigations made in recent years have shown that the scheme of volcanic activity

suggested by S.V. Obruchev (1932 - 1933) and later adopted by V.S. Sobolev [17] must be reexamined in the light of new data. This scheme, as is known, included the following succession of phases of vulcanism: first a tuff phase ( $C_3 - P_1$ ), then a phase of lava flows ( $P_2 - T_1$ ) and, finally, an intrusive phase ( $T_1$ ).

More recently M.M. Odintsov [8], A.P. Lebedev [6], M.L. Lurye and S.V. Obruchev [7], and V.A. Vakar [3] have suggested new successive phases of volcanic activity. Without stopping to criticize these suggestions, it will merely be said that all these investigators distinguish several extrusive and intrusive phases whose ages have been determined as Later Carboniferous to Early Jurassic inclusive.

The latest data on volcanic activity in the Tunguska syncline suggest a succession of phases such as the following:

##### A. Later Carboniferous - Early Permian

Tuffs and tuffaceous rocks of doleritic composition, at the bottom of the ore-bearing series. (Angara-Ilim district, Podkamennaya and Lower Tunguska).

Basalt lava blankets among the deposits of the Late Carboniferous (Noril'sk district).

Intrusive bodies (sills and dikes) of gabbro-diabase with clear traces of cataclism and metamorphism. Fragments of these rocks are contained in the tuff breccias of the tuffaceous suite (in the area of the lower reaches of the Kureyka River and of the Severnaya and Letnyaya Rivers). The occurrence of this phase of igneous activity within the Tunguska syncline is extremely irregular, as a result of the various amplitudes of the vertical movements of its individual parts. This stage of vulcanism as a whole coincides with the time at which the platform began to move from its relatively elevated position into subsidence.

##### B. Late Permian - Early Triassic

Formation of tuffs over an extensive area of the syncline, during a period of the most intensive ruptures and explosions. This phase was accompanied by the intrusion of an enormous amount of sills and dolerite dikes. The tuff and intrusive phase of vulcanism began at the same time as the intensive subsidence of the area of the syncline. Because of the subsidence, open fractures could not form in the upper layers of the

earth's crust, and the magma could thus emerge at the surface only through pipes created by explosions [7]. Hypabyssal intrusive bodies were formed below.

### C. End of the Early and Beginning of the Middle Triassic

Extrusion of basaltic lavas from fissures and volcanos. The composition of the lavas in certain cases changed toward alkaline basalts and picrites. Tectonically this phase coincided with the uplift of the northern and northwestern parts of the syncline and with the formation of fissures in the upper layers of the earth's crust that communicated with the upper surface. The whole southern and southeastern part of the syncline was subsiding tectonically at this stage, so that there could be no extrusions of basalt on the surface. Possibly, in view of V.A. Vakar's material on the oscillatory nature of the lava effusions in the north, in the southern half of the syncline at this stage there was an intrusive phase, which M.L. Lurye and S.V. Obruchev call a "post-lava intrusive phase with three subphases" and date in the Middle Triassic to Early Jurassic (?). There are still no data on the dates of each of the subphases; only their relative succession and the differences in composition associated with them are known.

The first subphase is represented by sills and laccoliths of undifferentiated dolerites and doleritic porphyrites, containing few volatile constituents.

The second subphase is made up of sills and dikes of differentiated gabbro-dolerite, and in the north of the syncline, of intrusions of ultrabasic and alkaline rocks.

The third subphase is characterized by undifferentiated gabbro-dolerites and dolerites; the igneous rock bodies are ring-shaped ellipses and ovals, and dikes and sills are formed as well (around the upper reaches of the Lower Tunguska River).

### D. Post-Early Jurassic (?)

This phase is represented by dikes and sills of diabases (dolerites) containing palagonite, and by intersection bodies (dikes, necks) of ataxitic diabase porphyrites; these are in the eastern part of the syncline.

The above scheme of the succession of igneous activity does not contain any phase of formation of the kimberlite pipes that are located in the areas linking the Tunguska

syncline and the Anabar antecline, as well as in the Tunguska and Vilyuy synclines. The most recent information indicates that these were formed after the Early Jurassic. There is reason to suppose that the formation of the kimberlite pipes more or less coincided with the intrusion of the ultrabasic and alkaline rocks in the north of the syncline.

Thus an examination of the locations of the ore districts, the succession of volcanic activity and the composition of the igneous rocks in the Tunguska syncline shows that the magnetite deposits are associated with tectonic fault structures along which intrusive bodies of basic rock were intruded up to the time the ore deposits were formed, in addition to the formation of the volcanic pipes.

The magnetite deposits were formed after the intrusion and crystallization of the magma of a given phase of igneous activity, and have no direct genetic connection with the intrusive bodies in the area of the deposits. The close physical connection between the intrusives and ore segregations and the common paths taken by the magmatic melt and the ore-bearing solutions point to a common source in a magmatic nucleus or chamber located at a certain, probably very great, depth. The existence of several stages of volcanic activity is an indication that there were probably also several stages in the formation of the deposits in the syncline. One can determine the connection between the magnetite ore formation and at least two of the stages of vulcanism. The formation of the Tunguska iron-ore field magnetite deposits, according to the data available, is associated with the earliest phase of volcanic activity, in the Late Carboniferous and Early Permian. After the formation of the so-called amphibolized gabbro-diabases, the ore-bearing solutions that precipitated the ores traveled from the same magma chamber along the same canals.

The formation of the magnetite deposits in the districts of the Bakhta, Podkamennaya Tunguska and Ilimpey Rivers, and in the Angara-Ilim district, was caused by one of the latest phases of volcanic activity, at the end of the Early and beginning of the Middle Triassic. The so-called differentiated gabbro-diabases were formed in the Bakhta and Podkamennaya Tunguska River district the solutions that deposited the ores traveled from the same magma chamber and for the most part along the same passages.

Differentiated traprock has not yet been found in the Angara-Ilim and Ilimpey districts; here the ore segregations cut across undifferentiated dolerites. Apparently the ore formation was produced by solutions that left the magma chamber, which lay at a certain depth and up to the time of mineralization

produced the bodies of dolerite. The pipes and fault cavities that were filled with dolerite, after being renewed by tectonic movements, also served as channels for the passage of solutions and for the deposition of the ores.

The existence of two different stages in the formation of the magnetite ores is also shown by the following fact. Along the middle reaches of the Ilimpey River, in the lower part of the tuff breccia stratum, together with fragments of gabbro-diabases and garnet-chlorite rocks are found fragments of magnetite ore from 5 to 15 cm in size. Here the tuff breccias are cut through by magnetite veins. The magnetites in the ore fragments and in the veins differ sharply in composition.

As regards the igneous rocks within the Tunguska syncline, the most outstanding fact is that all the types thus far known are the result of crystallization of almost exclusively basic magma.

It must be noted, however, that the differentiated gabbro-dolerites contain more acidic varieties, whose composition ranges all the way to that of quartz-diorites and less frequently to alkaline rocks such as essexite and analcime diabases (along the Bakhta River and its tributaries). These rocks, however, are not at all widespread.

Ultrabasic and alkaline rocks are known to occur in the north of the syncline; there are no granitoid rocks in this area.

Thus S.S. Smirnov's questions -- what is the source of the material making up the deposits, and by what passages was this material conveyed? -- may be answered as follows: the source of material in the magnetite ore deposits was the ore-bearing solutions that were separated at definite stages from the deep-seated basaltic magma chambers whose magma, up to the formation of the ore deposits, produced the traprock bodies in the upper structural level of the platform. So far two stages separated in time have been established with certainty in the segregation of the metalliferous solutions.

The passages by which the ore-bearing solutions traveled were those fault zones along which the basaltic magma that produced the traprock penetrated the upper structural level of the platform, until the ore deposits were formed. These deep-seated fault zones for a long time were mobile and repeatedly renewed. In such zones were localized the traprock bodies, the sometimes explosive volcanic pipes (necks) filled with tuffs and other rocks from the basaltic magma, and the bodies of magnetite ore.

Besides the close physical connection mentioned above between the zones of mineralization and the dike and sill traprock series, the association of the ores with the basic magma is also suggested by the contact mineralization around the traprock bodies. This mineralization is completely similar to that of the ore deposits under consideration (garnet-diopside and chlorite-calcite mineralization on the Ilimpey and Podkamennaya Tunguska Rivers, grossularite-vesuvianite accumulations on the Akhtaranda River, etc.).

These are the data obtained from studies of the region.

## 6. THE PROBLEM OF THE MIGRATION OF THE MATERIAL

S.S. Smirnov [14] and N.P. Anikeyev [1] have already discussed the question of the migration of the iron-bearing solutions. Their well-known opinion is that the iron in the magnetite deposits of the skarn type was transported as a haloid -- in the form of a chloride. S.S. Smirnov writes: "The copious amounts of apatite, which as a rule everywhere accompanies the magnetite in these veins, make it possible to suggest that the iron migrated as a haloid, although there are serious objections to this idea. Thus the suggestion arises that hydrocarbons, in one combination or another, may have played a large part in facilitating the migration of the iron."

Without dwelling on the general question of the migration of iron in haloid form, the present author wishes to call attention to one very important fact. Wherever magnetite ore formation is known to have taken place there are also sources of salt or even deposits of halite. In the Tunguska iron-ore field, for example, on the Severnaya River (a tributary of the Lower Tunguska) there are sources from which salt has been mined. Around the lower reaches of this river (on the tributary below the rapids) there are also sources of salt. On the Podkamennaya Tunguska, at the mouth of the Rassolka River, is a salt works. Among the Ilim deposits of the Angara-Ilim district there are salt deposits near the Shestakovo forest and in other places.

The Lower Cambrian stratigraphy of the Tunguska syncline and the adjoining areas shows quite clearly that deposits of evaporite and high-salinity basins are widespread throughout these areas.

The area of the lower reaches of the Lower Tunguska and Kureyka Rivers, and the northeastern part of the Tunguska

syncline in the zone in which it connects with the Anabar syncline, according to information from V.V. Manner (1957), are known to contain a salt-bearing formation of Devonian age.

From the facts given above it may be assumed that the haloid compounds in the iron-bearing solutions may have been created by interaction of the basaltic magma and the salt deposits. The above-mentioned differentiated gabbro-dolerites, which include some highly alkaline rocks, also suggest the possibility of processes of xenohybridism. It is now becoming more and more clearly established that processes of contamination and hybridism were of no small importance in the formation of the traprock intrusives [6].

## 7. SOME OTHER PROBLEMS OF GENESIS

S.S. Smirnov has pointed out that the considerable introduction of such elements and components as Fe, Ca, Mg, H<sub>2</sub>O, CO<sub>2</sub>, P, (Cl, F) in the formation of the deposits corresponds more closely to basic than to acidic magmas. N.P. Anikeyev, completely dissociating himself from S.S. Smirnov's views, noted that the chemistry of the Angara-Ilim district deposits differs sharply from that of the vein deposits associated with granitic magma, since silicic acid plays a negligible role in the formation of the ores and such elements as K, Na, Li, B and certain others are completely absent. A detailed study of the mineral and elemental composition of the ores and the surrounding zones of alteration, made by the present author in the deposits of all four of the iron-ore districts, shows that the following elements must be added to the list of those recorded in the composition of the ores: titanium, vanadium and cobalt. The titanium and vanadium form part of the basic ore mineral -- magnesiferous magnetite. It is of interest to note, for example, that in the Kamyshevskiy Baykitik deposits, which are of undoubted industrial importance, the content of V<sub>2</sub>O<sub>5</sub> in the magnesiferous magnetite is as much as 0.6 percent by weight, and that of cobalt in the pyrite as much as 0.2 percent. There is no need to show that these elements are typical of basic magmas.

In regard to the third and fourth questions posed by S.S. Smirnov -- how was the material deposited at the points where deposits now exist (this involves the composition, the structure and texture, the occurrence of the ores, etc.), and what alterations did the deposits undergo? -- the following things must be pointed out.

K.I. Bogdanovich, S.A. Doktorovich-

Brebnitskiy, S.S. Smirnov and N.P. Anikeyev have already answered these questions quite fully in respect to the Angara-Ilim deposits. S.S. Smirnov has said that "far more data are available to answer the third and fourth questions."

Thus this discussion will be confined to certain new, but peculiar, aspects.

The following succession has been noted in the paragenesis of minerals in the deposits of the Angara-Ilim district:

- 1) garnet (grossularite - andradite) -- diopside, magnetite, apatite;
- 2) magnetite, apatite, serpentine, chlorite, calcite;
- 3) calcite, magnetite, hematite, chlorite;
- 4) quartz (amethyst), chalcedony, calcite.

This paragenesis, with a few exceptions here and there, has been maintained by the majority of investigators both in the earlier and the more recent periods in which the deposits have been studied. It is, in fact, supported by a considerable body of factual data.

This scheme, however, is not a universal one and cannot be extended to all the iron-ore districts of the Tunguska syncline. For example, a number of deposits in the second of the ore districts enumerated in this article, on the lower reaches of the Podkamennaya Tunguska River (the Chernaya River, the Khakdasik and other deposits) another succession of paragenetic associations has been observed:

- 1) magnetite, diopside, basic plagioclase (nos. 45 - 55), apatite, garnet;
- 2) actinolite, prehnite, epidote, chlorite, zeolites, calcite.

In these deposits, as in those of the Angara-Ilim district, there has been extensive metasomatism by infiltration. The oolitic limestones have undergone replacement. The magnetite segregated in the earlier stages of formation of the ore bodies differs essentially from the magnetite in the Angara Ilim district deposits in the lack of magnesium in its composition. The presence of basic plagioclase in the ores testifies to the introduction of sodium.

It has been said above that the deposits around the lower reaches of the Podkamennaya Tunguska and Bakhta Rivers are physically connected to the differentiated gabbro-dolerites. Within these rocks are

ones of strongly albitized dolerites in which the pyroxenes are partially replaced by more alkaline amphibole.

The following minerals have been found in the composition of the ores in the deposits of the Tunguska iron-ore field (on the Kureyka, Tevernaya and Letnyaya Rivers): olivine occurs sporadically, sahlite, garnet, apatite, magnesiferous magnetite (low in MgO), wollastonite, scapolite, actinolite, biotite, chlorite, serpentine, zeolites, calcite, clinzoisite, sericite, talc, quartz, chalcedony. The metagranites have undergone metasomatic replacement.

Two stages have been observed in the deposition of the ores: 1) olivine, sahlite, garnet, wollastonite, apatite, magnesiferous magnetite; 2) actinolite, biotite, chlorite, serpentine, zeolites, epidote (clinzoisite), sericite, talc, quartz.

One more group of facts must be taken into account in discussing the mineralization and ore deposition. It is known that the majority of ore veins and segregations of blockade ores and brecciated ores of the Angara-Ilim district have a colloform structure; thus there can be no doubt that colloidal ore-bearing solutions played a great part in the deposition of the ores.

The present author's investigations of the textures and structures of the ores and their host rocks, and of the paragenetic minerals, have disclosed the following probable succession in the evolution of the solutions. The high-temperature stage of mineral formation — the segregation of pyroxene, garnet, and part of the magnetite and calcite — took place through the interaction of ionic-molecular true solutions with the host rocks. As the temperature was lowered and open vein shaped cavities appeared, new processes of mineral formation began. Water, carbon dioxide and certain other components, interacting with the host rocks and the minerals segregated earlier, caused the formation of chlorite, serpentine, zeolites, calcite and certain other minerals. In the fissures the solutions became oversaturated, turned into colloidal solutions and deposited the ores in the form of gels. In other words, colloidal solutions were formed at the points where the ore material was deposited.

The final stage in the deposition of the ores from colloidal solutions is marked by the formation of oolitic ores [11]. As the temperature was lowered still further after the formation of these ore varieties, the solutions, which still contained no iron compounds, again became true solutions, and such minerals as chlorite, calcite, quartz and chalcedony were separated out. The

lower temperature limit for the existence of the colloids in this case may be reckoned as 180° to 225°. This is determined by measuring the homogenization temperature of the gaseous and liquid inclusions in the quartz (amethyst). The upper temperature limit for the formation of colloidal solutions may be measured approximately by the temperature at which the garnet is formed. Thus far, however, no gaseous and liquid inclusions have been encountered in the garnets.

It must be stressed, in conclusion, that the magnetite ore veins deposited from colloidal solutions have undergone recrystallization, which often has produced fibrous and acicular aggregates or columnar grains of magnetite.

## CONCLUSIONS

1. In the Tunguska syncline of the Siberian platform, in addition to the Angara-Ilim iron-ore districts have been discovered whose deposits are also associated with the volcanic activity that produced the traprock.

Each of the iron-ore districts, being located in a specific part of the regional deep-seated fault zones that surround the Tunguska syncline, is characterized by its own special geologic conditions governing the localization of the ore segregations. A feature common to the deposits of all the iron-ore districts of the syncline is the close association between the mineralization and the faults along which the magma that formed the conformable and unconformable traprock bodies traveled, until the formation of the ores. Later tectonic movements renewed the fault zones, and the ore formation was localized principally in the inherited fault zones and belts.

2. The formation of the magnetite ore deposits was due to metalliferous solutions that were separated at definite stages of the volcanic activity from the deep-seated nuclei of basaltic magma. In the present state of our knowledge of these matters, two stages have been reliably established in the separation of the ore-bearing solutions from the magma chamber and the formation of the deposits. The first stage is connected with the magmatic phase that appeared in the Late Carboniferous and Early Permian; the second with the very latest phase of igneous activity in the Late Triassic or even Early Jurassic (?).

3. The paths taken by the penetrating metalliferous solutions were the tectonically renewed fault zones along which the basaltic magma had traveled into the upper structural

level of the platform until the formation of the deposits. The ore mineralization was localized in both the fault zones and the accompanying zones of weakened rock conformable with the bedding and in the pipes (necks) distributed throughout the more mobile parts of the Tungusska syncline.

4. During the formation of the deposits the ore-bearing solutions, besides water and carbon dioxide, contained Fe, Ca, Mg, Ti, V, Co (Ni), P, Cl, F. The iron was most probably contained in the form of chlorides and fluorides. The iron chlorides may have been of juvenile origin and, more likely, may also have been created by interaction of the basaltic melt with the halite deposits of the Lower Cambrian. The presence of alkaline facies in the differentiated traprock bodies and the manifestation of xenohybridism are both in accord with this supposition.

5. The paragenetic mineral associations, as well as the composition of the magnesian magnetite, vary according to the concrete geologic conditions -- the tectonic structures, the composition of the host rocks, and the distance from the localization of the ore formation to the deep-seated magma chamber.

The ore segregations farthest removed from the magma chamber are characterized by low-temperature paragenetically associated minerals -- magnetite, serpentine, chlorite, calcite, quartz. The magnetite contains up to 75 to 80 percent of  $MgFe_2O_4$  and is thus magnesioferrite (in the Ilmpey district deposits). Garnet and pyroxene are not typical. The host rocks are doleritic tuffs.

In the case of deposits that are somewhat closer to the magma chamber and are contained in the tuffs, dolerites, argillites, and marls (of the Angara-Ilm district), a rather different sequence of mineralization has been established. This includes, first of all, an extensive high-temperature stage:

1) grossularite-andradite, diopside, magnetite, apatite; in addition, three relatively low-temperature stages are distinguished:

2) magnetite, apatite, serpentine, chlorite, calcite;

3) calcite, magnetite, hematite, chlorite;

4) quartz (amethyst), chalcedony, calcite.

The magnetite contains from 3 to 50 percent  $MgFe_2O_4$ , and may thus be considered to be magnesiferous magnetite.

In the case of the deposits whose formation is associated with the metasomatic replacement of the carbonate rocks (limestone and dolomite), the paragenetically associated minerals are different from those of the preceding deposits. Thus two stages of mineralization have been noted in the Podkamennaya Tunguska River deposits:

1) magnetite, diopside, basic plagioclase, apatite, garnet;

2) actinolite, prehnite, epidote, chlorite, zeolites, calcite.

The magnetite here does not contain magnesium.

Two stages of mineralization have also been observed in the deposits of the Tunguska iron-ore fields (on the Kureyka, Severnaya and Letnyaya Rivers):

1) olivine, sahlite, garnet, wollastonite, apatite, magnetite;

2) actinolite, biotite, chlorite, serpentine, zeolites, clinozoisite, sericite, talc and quartz.

The magnetite is low in magnesium, containing less than 5 percent of  $MgFe_2O_4$ .

6. Along with the widespread manifestation of metasomatism by infiltration in the formation of the deposits, a very important role in the deposition of the ore veins was played by colloidal solutions which developed from true solutions by supersaturation of the latter at the point where the ore material was deposited; these colloidal solutions did not emerge as such from the deep-seated magma chamber.

7. Certain deposits clearly show a recrystallization of the colloidal ore solution with a formation of strikingly elongated acicular and fibrous grains of magnetite.

## REFERENCES

1. Anikeev, N.P., OCHERK ZHELEZORUDNYKH MESTOROZHDENIY ANGARILIMSKOGO RAYONA [A BRIEF DESCRIPTION OF THE IRON-ORE DEPOSITS OF THE ANGARA-ILIM DISTRICT]: Tr. Vost.-Sib. Geol. Tresta, Vyp. 19, 1936.
2. Bogdanovich, K.I., MATERIALY PO GEOLOGII I POLEZNYM ISKOPAYEMYM IRKUTSKOY GUBERNII [DATA ON THE GEOLOGY AND THE ORE MINERALS OF THE IRKUTSK GUBERNIYA]: Geol.

- Issled. i Razved. Raboty po Linii Sib. Zh. D., Vyp 2. Saint Petersburg, 1896.
3. Vakar, V.A., OSNOVNYE CHERTY MAGMATIZMA SIBIRSKIKH TRAPPOV [THE BASIC FEATURES OF THE IGNEOUS ACTIVITY ASSOCIATED WITH THE SIBERIAN TRAPROCK]: Inform. Byul. Instituta Geol. Arktiki, Vyp. 1, 1957.
4. Doktorovich-Grebnitskiy, S.A., OCHERK ZHELEZNYKH MESTOROZHDENIY NIKOLAYEVSKOGO ZAVODA IRKUTSKOY GUBERNII [A BRIEF DESCRIPTION OF THE IRON DEPOSITS OF THE NIKOLAYEV WORKS IN THE IRKUTSK GUBERNIYA]: Tr. Glavn. Geol.-Razved. Upr., Vyp. 33, 1931.
5. Kosygin, M.K. and G.V. Roslyakov., K VOPROSU O STRUKTURE I GENEZISE ANGARO-ILIMSKIKH ZHELEZ-NORUDNYKH MESTOROZHDENIY [THE PROBLEM OF THE STRUCTURE AND GENESIS OF THE ANGARA-ILIM IRON-ORE DEPOSITS]: Tr. Irkutsk. Gorno-Metal. Instituta, Vyp. 10, Ser. Geol., 1956.
6. Lebedev, A.P., TRAPPOVAYA FORMATSIYA TSENTRAL'NOY CHASTI TUNGUSSKOGO BASSEYNA [THE TRAPROCK FORMATION IN THE CENTRAL PART OF THE TUNGUSKA BASIN]: Tr. Instituta Geol., Nauk, Akademiya Nauk SSSR, Ser. Petrogr., Vyp. 161, 1955.
7. Lurye, M.L. and S.V. Obruchev, OSNOVNYE CHERTY EFFUZIVNOGO VULKANIZMA TRAPPOVOY FORMATSII SIBIRSKOY PLATFORMY [THE BASIC FEATURES OF THE EXTRUSIVE VOLCANIC ACTIVITY ASSOCIATED WITH THE TRAPROCK FORMATION OF THE SIBERIAN PLATFORM]: Materialy po Geol. Sibirskoy Platformy. Gosgeolizdat, 1955.
8. Odintsov, M.M., IRKUTSKIY AMFI-TEATR [THE IRKUTSK CIRQUE]: Tr. Irkutsk. Gos. Universiteta, t. 6, Vyp. 2, 1954.
9. Offman, P. Ye., O VULKANICHESKIKH TRUBKAKH YUZHNOY CHASTI SIBIRSKOY PLATFORMY I O PROISKHOZHDENIY ZHELEZNYKH RUD, PRIYOCHENNYKH K ETIM TRUBKAM [THE VOLCANIC PIPES OF THE SOUTHERN PART OF THE SIBERIAN PLATFORM AND THE ORIGIN OF THE IRON ORES ASSOCIATED WITH THEM]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 10, 1957.
10. Offman, P. Ye., O STROYENII TSENTRAL'NOY CHASTI SIBIRSKOY PLATFORMY [THE STRUCTURE OF THE CENTRAL PART OF THE SIBERIAN PLATFORM]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 11, 1956.
11. Pavlov, N. V., O GIPOGENNIKH MAGNETIT-GEMATITOVYKH OOLITAKH IZ ZHELEZORUDNYKH MESTOROZHDENIY ANGARO-ILIMSKOGO RAYONA [THE HYPOGENETIC MAGNETITE AND HEMATITE OOLITES IN THE IRON-ORE DEPOSITS OF THE ANGARA-ILIM DISTRICT]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 4, 1956.
12. Pavlov, N.V. and I. I. Chuprynina, O MAGNOMAGNETITAKH KAK INDIKATORAKH GLUBINNOSTI ORUDENENIYA [MAGNETIFEROUS MAGNETITES AS INDICES OF THE DEPTH OF MINERALIZATION]: Dokl., Akademiya Nauk SSSR, t. 104, no. 2, 1955.
13. Smirnov, S.S., ZHELEZORUDNYE MESTOROZHDENIYA VOSTOCHNOSIBIRSKOGO KRAYA [THE IRON-ORE DEPOSITS OF THE EASTERN BORDER OF SIBERIA]: Irkutsk, 1931.
14. Smirnov, S.S. K MINERAGENII SREDNESIBIRSKOY PLATFORMY [THE GENESIS OF THE MINERALS OF THE CENTRAL SIBERIAN PLATFORM]: Probl. Sov. Geologii, t. 4, no. 10, 1933.
15. Smirnov, S.S., ANGARO-ILIMSKAYA ZHELEZORUDNAYA PROVINTSIYA [THE ANGARA-ILIM IRON-ORE PROVINCE]: Razvedka Nedr, no. 20, 1933.
16. Sobolev, V.S., GEOLOGO-PETROGRAFI-CHESKIY OCHERK R. ILIMPEY [A BRIEF DESCRIPTION OF THE GEOLOGY AND PETROGRAPHY OF THE ILIMPEY RIVER]: Izv. Vses. Geogr. O-va, no. 6, 1935.
17. Sobolev, V.S., PETROLOGIYA TRAPPOV SIBIRSKOY PLATFORMY [THE PETROLOGY OF THE TRAPROCK OF THE SIBERIAN PLATFORM]: Tr. Arkitch. N.-I. Instituta, Vyp. 43, 1936.
18. Spizharskiy, T.N., O VOZRASTE VULKANOGENNYKH OBRAZOVANIY SIBIRSKOY PLATFORMY [THE AGE OF THE VOLCANOGENIC FORMATIONS OF THE SIBERIAN PLATFORM]: Materialy po Geol. Sibirskoy Platformy Gosgeolizdat, 1955.

Institute for the Study of the Geology,  
Petrography, Mineralogy and Geochemistry  
of Ore Deposits of the U.S.S.R.  
Academy of Sciences  
Moscow

Received March 12, 1958

# SOME PECULIARITIES OF THE STRUCTURE OF THE MAYTAS GRANITE MASSIF (IN THE NORTHERN PRIBALHASH AREA) AND THE DISTRIBUTION OF CERTAIN RARE ELEMENTS IN IT

by

V. V. Buldakov

In studying the joint structure of intrusives the special interest of investigators has been drawn to igneous rock masses that enclose ore veins, where a detailed analysis of the jointing will facilitate discovery of the factors governing the localization of the ore formation and of the prospects for development. Unfortunately, investigators are often content with determining the interrelationships in time of veins with different compositions, whereas the history of the ore-bearing joints, which would make it possible to reconstruct the laws governing the formation of both the intrusives themselves and the ore deposits associated with them, are given insufficient study.

The Maytas granitic massif in the Northern Pribalkhash area (Central Kazakhstan) will serve as the basis for an attempt to examine certain features of joint structure that will enable one to some degree to determine the conditions of the formation of the intrusive, its form and its relation to the geologic development of the area under consideration.

## SOME FEATURES OF THE GEOLOGIC STRUCTURE OF THE AREA

The structure of the area (Fig. 1) is made up of a complex of lithologically different extrusive and sedimentary rocks which can be roughly divided into series: a lower sedimentary series, a middle extrusive series and an upper extrusive-sedimentary series. These series compose the northeastern part of the eastern flank of the Kyzyl-Espa anticlinorium. The trend of the folds is predominantly NW  $310^{\circ}$  to  $330^{\circ}$ , although folds trending northeast are sometimes encountered. The dip of the folds in the lower series varies from  $30^{\circ}$  to  $40^{\circ}$  and in the upper series becomes gentler, down to  $15^{\circ}$  to  $25^{\circ}$ . The trend of the folded structures is maintained, and only the steepness of the dip of the flanks changes.

The lack of faunally defined strata in the

extrusive-sedimentary series, and their somewhat different lithologic composition from that of the nearby areas, make it impossible to determine accurately the age of the rocks composing the district. According to V.F. Bepalov [1, 2], the extrusive rocks of the Northern Pribalkhash area, including the district under consideration here, belong to the Early Carboniferous and Later Paleozoic, and not to the Devonian as suggested by N.G. Kassin, N.I. Nakovnik, M.P. Ruskov and other investigators.

The lithologic composition of the series that have been distinguished in this area is as follows.

The lower sedimentary series is basically made up of polymict and tuffaceous sandstones, replaced above by a thin (up to 1.5 to 2.0 m) interbed of conglomerates underlying a rather thick stratum of acidic coarse grained tuffs and tuff breccias. The whole series extends over a large area, has a thickness on the order of several hundred meters and lies mainly in the southern half of the district under consideration.

The middle extrusive series, whose thickness is probably on the order of 200 to 300 m, begins with a layer of tuffites which frequently change horizontally to siliceous shales; above this lie (from below upward) diabases, diabase porphyrites, amygdaloids, and plagioclase andesitic porphyrites and their tuffs, with interlayerings of dacite porphyrites.

The upper sedimentary-extrusive series differs from the middle series in the more acidic composition of its rocks, which consist of coarsely fragmental tuffs of liparite porphyries in a thick stratum overlain by a layer of felsitic lavas, above which are individual spots of liparite porphyries. The entire series of acidic extrusives has a characteristic reddish color.

The uppermost and youngest formations of the district are the mantles of trachyliparite

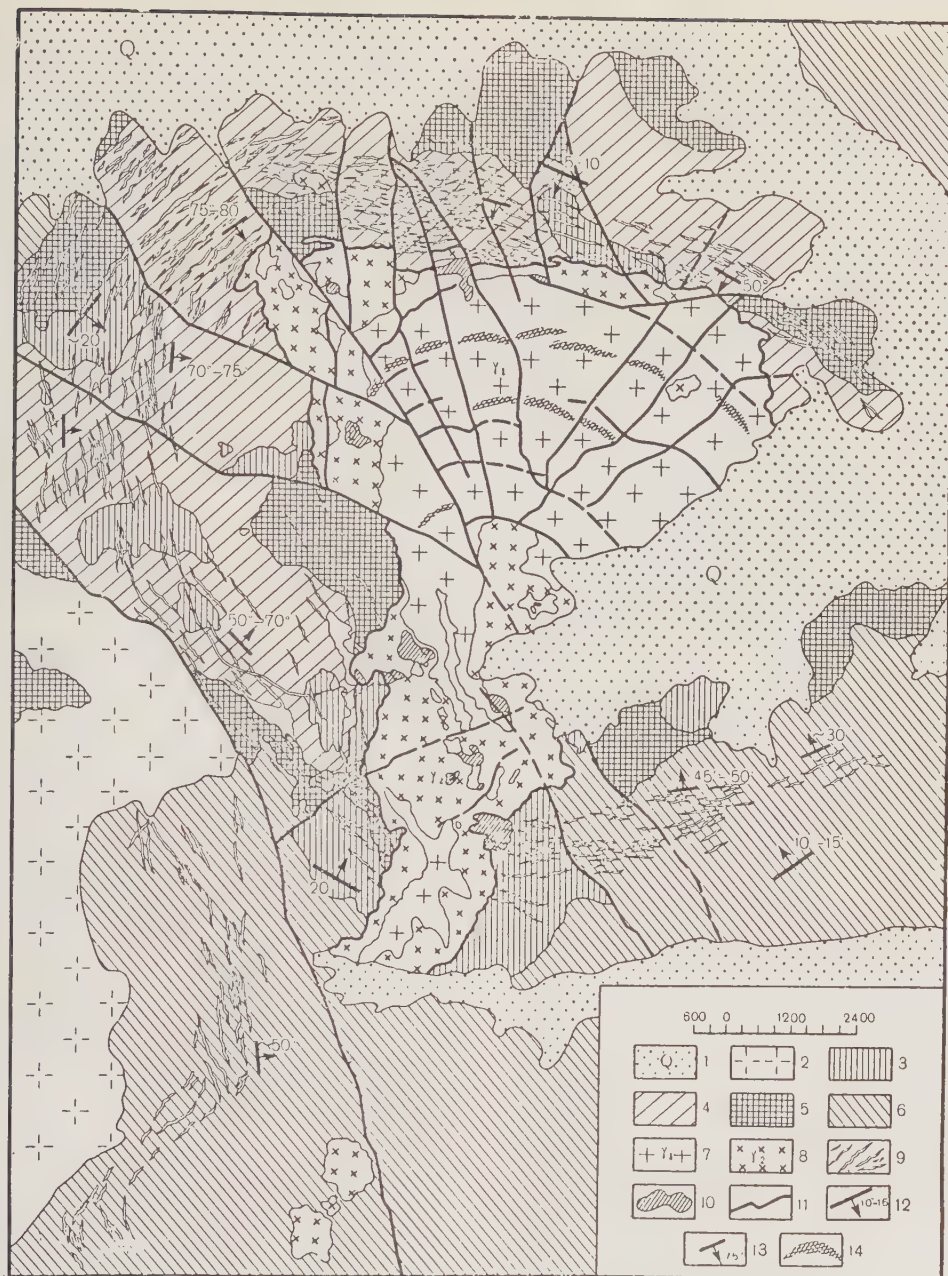


Fig. 1. Geologic map of the Maytas granite massif.

1 -- Recent sediments; 2 -- trachyliparite porphyries; 3 -- acidic intrusives and their tuffs; 4 -- diabases and diabase porphyrites; 5 -- andesitic plagioclase porphyrites and their tuffs; 6 -- tuffs of liparitic porphyries and tuffaceous sandstones; 7 -- coarse and medium-grained granites; 8 -- fine-grained porphyritic granites; 9 -- dikes of granite porphyry; 10 -- host rock xenoliths in the granites; 11 -- tectonic faults; 12 -- symbols showing the mode of occurrence of the host rocks; 13 -- symbols showing the disposition of the dikes of granite porphyry; 14 -- zones of distribution of aplite dikes and small pegmatite bodies.

porphyries.

The entire complex of rocks is cut through by granites; the granite intrusive was injected into the core of a small local brachysynclinal structure, whose flanks dip quite gently, from  $5^{\circ}$  to  $20^{\circ}$ . The syncline is surrounded by a series of conically shaped faults along which granite-porphyry dikes were intruded. These dikes always dip toward the center of the syncline, at angles of  $40^{\circ}$  to  $50^{\circ}$  in the south and  $60^{\circ}$  to  $80^{\circ}$  in the north. The difference in the angles of dip produces a certain asymmetry in the section through the ring-shaped zone of conical dikes. Granites cut the zone of ring dikes in the southern part of the area, which indicates that they are younger than the granite porphyries. The conical faults in all probability were the channels for the lavas that produced the youngest rocks of the district, the trachyliparite porphyries. The proof of this is the fact that the trachyliparite series are not cut by the granite porphyry dikes, and the almost identical mineral composition and structure of these rocks.

The massif is made up of several varieties of granite. The center is composed of large-grained porphyritic biotite granites, and the periphery of medium-grained varieties which are the border facies of the large-grained granites. In "sills" extending from 5 to 50 m, and from 100 to 150 m at the edges of the massif (according to data from bore holes), there is a quite extensive variety of fine-grained, strikingly porphyritic, alaskite granite. The contact between the alaskite granite and the large- and medium-grained granites is often quite distinct, and is characterized by the presence of a chilled zone, which indicates that the alaskite was intruded later. These granites are extensively distributed along the northwestern, western and southwestern contacts of the Maytas granite massif in the form of an almost continuous semicircle. The veins associated with the granite massif are represented by aplite dikes and lens-shaped bodies of pegmatites.

The host rocks at the contact with the granite have been altered to hornstone and granophyric rock. The latter are recrystallized acidic extrusives with a clear micrographic and micropegmatitic structure.

It must be noted that, in addition to the conical faults along which the granite porphyry dikes were injected, the area under consideration contains two quite large faults striking north-northwest ( $320^{\circ}$  to  $330^{\circ}$ ) and one striking east-northeast ( $70^{\circ}$  to  $80^{\circ}$ ). These faults are regional in extent and can be traced for a great distance.

There is also an important system of

radial faults. These divide the area, especially its northern half, into a number of wedge-shaped blocks, which are considerably displaced relative to each other both horizontally and vertically; this displacement is especially clearly seen along the northwestern contact of the granite massif. The movement of these blocks is conspicuous for the displacement of the strata of the host rocks and for the considerable amount of cataclasis of the granites in the fault zones, which is accompanied in individual cases by tectonic breccia, slickensides and zones of quartz formation. It is typical that the radial faults in most cases gradually die out toward the south and run together in one area in the center; as one moves away from this, the vertical amplitude of the displacement increases.

#### THE JOINT STRUCTURE OF THE INTRUSIVE

Before moving on to an analysis of the internal structure of the granite massif, and particularly of its joint pattern, the data on its overall shape must first be examined.

The Maytas massif is an intrusive body, elongated in the north-south direction and widening toward the north. Its contact surfaces dip steeply (as much as  $60^{\circ}$  to  $70^{\circ}$ ) toward the host rocks. In view of their general occurrence, it must be concluded that the intrusive is unconformable. The upper surface of the granite massif is fairly flat and inclines gently toward the southeast. The northern contact of the massif with the host rocks is also quite flat; the western contact is more broken, since the individual blocks of the massif here are displaced to considerable distances as a result of tectonic movement. The southeastern contact is covered by sediments of recent age.

Because of the almost complete exposure of the granite massif, the elements of its internal structure are easily seen. The map shown in Figure 2 indicates that the massif is broken up by a dense system of joints running in various directions; there are four main systems of vertical and one system of gently sloping joints. The role played by the joints running in one direction or another is related to the structure of the granites and their geologic position.

The system of gently inclined joints, which differ sharply in granites of different textures and compositions, is particularly important. In the large-grained granites the gently sloping joints are somewhat less extensive; ellipsoidal structures are usually formed here as a result of such jointing. In the fine-grained granites the gently inclined jointing is more

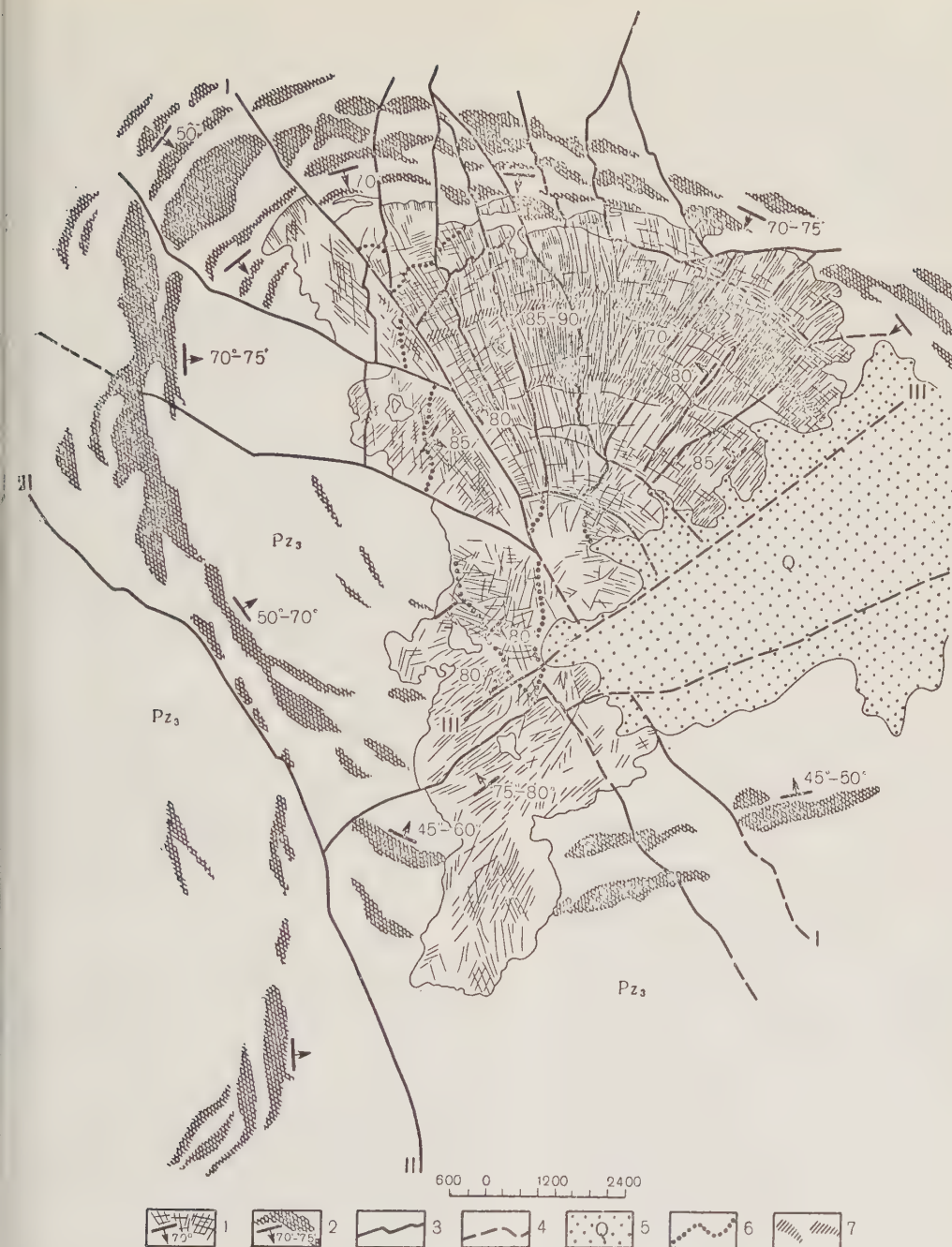


Fig. 2. Map showing the joint structure of the Maytas granite massif.

1 -- primary jointing in the granites and symbols showing its occurrence; 2 -- zones of granite porphyry conical dikes and symbols showing their occurrence; 3 -- known faults; 4 -- supposed faults; 5 -- Recent sediments; 6 -- boundary between fine-grained porphyritic rocks and medium and coarse-grained granites; 7 -- zones of distribution of aplite dikes and small pegmatite bodies.

extensive, so that the rock here is usually broken up into thin slabs no more than 10 to 12 cm wide. The gently inclined joints change their dip sharply even within small spaces and evidently reflect the shape of the granite intrusive's surface. Bodies of fine-grained strongly porphyritic granites of various thicknesses occupy considerable areas among the gently sloping joints in the large and medium-grained granites.

The greatest interest is presented by the steeply dipping joint systems, which are distributed with a definite regularity. In the case of the large- and medium-grained granites (east of fault I in Fig. 1), concentric and especially radial joint patterns are the most typical. They are spaced at considerable distances in the form of clusters radiating from the center of the intrusive, and can be traced without change from the granite for a certain distance into the surrounding rocks. In the eastern part of the massif the joints dip westward at an angle of  $70^{\circ}$  to  $85^{\circ}$ ; in the western part the dip is in the opposite direction at the same angle. Such joints usually have no filling, but sometimes only a small amount of low-temperature quartzification of the rocks is observed in them.

The concentric joints appear less clearly on aerial photographs, but they can easily be followed on the ground, since they are very frequently associated with aplite dikes and small (no greater than 0.5 to 2.0 m in width) almost isometric bodies of pegmatites. Such formations are especially widespread in the northern, most elevated part of the massif which, to judge by the extent of the large-grained granites, has been tectonically uplifted and more deeply eroded. The joints in the concentric system dip steeply, as much as  $75^{\circ}$  to  $85^{\circ}$  to the south -- that is, toward the center of the intrusive -- and, like the radial joints, can be traced into the surrounding rocks, but for a much shorter distance.

Both the radial and the concentric fissures involve movements characterized by normal as well as oblique-slip faults, often with a horizontal displacement of considerable amplitude. The displacements in the planes of the radial joints are in every case later than those of the concentric fissures, since they almost always involve blocks formed by the latter. These displacements are especially well marked in the aplite dikes, which for the most part occupy the conformable concentric fissures.

This block of the massif also contains two systems of vertical fissures, which correspond in direction to the basic faulted structures of the district -- north-northwest and east-northeast (NNW  $320^{\circ}$  to  $330^{\circ}$  and ENE

$70^{\circ}$  to  $80^{\circ}$ ). But these joints are of little importance in the large- and medium-grained granites. In the fine-grained granites located mainly to the west of fault I, on the other hand, both of these systems are quite prominent (Fig. 2). The joints striking east-northeast are of great importance, inasmuch as they often contain high-temperature ore-bearing quartz veins with associated greisens. The north-northwest joints are, for the most part, not mineralized.

The dips of the steep joints are also characterized by certain regular features. Thus, for example, the joints that follow the parallels of latitude (north-northeast) in the southern part of the fine-grained granite area dip northward; in the northern part, like the ore veins, they dip in the opposite direction. The angles of dip are steep, about  $80^{\circ}$  to  $90^{\circ}$ . In the area described, west of fault I, there are two more systems of steep joints that intersect the first two systems -- north-northwest and east-northeast -- at an angle of  $45^{\circ}$ . Sometimes these joints change their strike to form an arc and, in a manner of speaking, reflect the concentric system of joints in the main block of the intrusive (east of fault I).

Thus the granite massif may be divided into two parts which differ in the nature and direction of the joint patterns developed in them. This difference is determined not only by the heterogeneous nature of the rocks composing these areas, but mainly by the different times at which the jointing appeared in the general course of the geologic history of the district.

#### THE RELATIONSHIP BETWEEN THE JOINTING AND SHAPE OF THE INTRUSIVE AND THE GENERAL STRUCTURE OF THE DISTRICT

Analysis of the joint structure of the granite massif has established the close connection of the intrusive's development with the overall geologic history of the district, as well as a certain relationship between the peculiar distribution of the jointing and the shape of the intrusive body.

The brachyanticlinal fold and the zone of ring dikes in its flanks have also been reflected in the shape of the intrusive itself. Figures 1 and 2 show that the original shape of the massif in plan was, apparently, circular and thus concordant with the general shape of the brachyanticline. This can be seen especially well at the northern contact of the granites with the host rocks, which is here exactly parallel to the zone of granite porphyry ring dikes that were intruded along the dense net of concentric faults.

A certain asymmetry of the southern contact, where the intrusion cuts the zone of dikes, is in all probability determined by the nature of the faults along which the granitic magma was injected. Such faults in the district under consideration may have been those whose trend runs north-northwest, which predetermined the massif's meridional elongation that was later increased partly by repeated movements along the north-northwest faults and mainly by fault I.

The circular shape of the massif in the initial period of its formation, when the upper parts had been totally congealed, caused the formation of a net of contraction joints. One system of joints was radial and the other concentric. The concentric joints became strictly parallel not only to each other but also to the line of contact between the massif and the separate elements in the internal structure of the host rocks; this is confirmed by the position of the ring-shaped zone of conical dikes of granite porphyry. The dip of this joint system in the granites typically corresponds to the dip of the earlier concentric faults in the host rocks, with which the granite porphyry dikes that are older than the granites are often associated.

The probability that the joints in the granites were produced by contraction is seen in their uniform distribution during the formation of the dense net throughout the whole area of the massif (up to several thousand joints per km<sup>2</sup>) and in the fact that they are maintained over great distances. The space separating individual joints in the same direction is no greater than 20 to 30 cm. It is difficult to imagine any other origin for such joints, especially those of the radial system.

The concentric fissures in the host rocks and in the granite intrusive are typically filled with dikes. In the former they are granite porphyries; in the latter they are often aplites or pegmatites (see Fig. 1). The sharp difference in their ages is important in solving the question of the temporal relationships between the magmas. The granite porphyries are thus older than the granites, whereas the aplites and pegmatites are younger. It is important to note that there was an infiltration of igneous material along the system of concentric faults in the host rocks both until the granitic magma was intruded and after its intrusion; this material was cooled in the upper strata (forming the aplite dikes and pegmatite bodies). This shows that the concentric fissures at certain moments served as paths for the injection of the igneous melts and, in some cases, of post-magmatic solutions. It must also be kept in mind that the dip of the concentric fissures and thus of the dikes as well is the same both in the host rocks and in the

massif, and inclines toward the center of the structure. The radial system of joints and faults is almost never found to contain material forming dikes, in spite of the fact that it evidently extends to great depths.

This disposition of the main elements of the internal structure of the massif, and especially of the concentric jointing, may be taken as an indication that the channel feeding the igneous melt was primarily in the center of the brachyanticline, where the clusters of conical granite-porphyry and aplite dikes interlock. In this process, part of the igneous melt rose along the steeply inclined channels, reached the surfaces of the exfoliation that formed the other, gently sloping system of joints, and spread out along these to form a complex net of gently sloping and vertical dikes connecting the bodies of fine-grained aplitic granites and the aplites. The other part of the fine-grained porphyritic granites which formed a thick stratum along the western contact of the massif, west of fault I, was evidently intruded along the hanging contact surface of the granite massif.

The portion of the granitic massif to the west of fault I and composed of primarily fine-grained strongly porphyritic granites is essentially different from the portion to the east of the fault. Here, too, there is a strict regularity in the development of the joint structure relative to the fundamental tectonic structure of the district. The formation of the joints striking north-northwest and east-northeast is associated with the formation of the large faults running in the same directions (faults I, II, III). The elements in the internal structure of the fine-grained granites were probably formed in association with the formation of the large and medium-grained granites. This is understandable, since the magmas producing the fine-grained granites were being intruded while the earlier large- and medium-grained granites in the upper levels were uncrystallized. The most deeply penetrating joints, mainly concentric, which had appeared in these large-grained granites, served as passages for the intrusion of the magmas of the fine-grained granites. Until the magma was solidified there was a renewal of tectonic movement, which produced repeated movements along the north-northwest and east-northeast faults that had been emplaced earlier, as well as the formation of new faults with the same strikes in isolated parts of the large- and fine-grained granites (the latter could occur only in deformations accompanied by rupture). The poor development of contraction joints in these granites is apparently due to the fact that their solidification was accompanied by tectonic movements resulting in the formation of joints with the same strikes as the joints and faults in the host rocks. Residual

hydrothermal and pneumatolytic solutions penetrated along one of the joint systems -- mainly the east-northeast -- into the intrusive and led to the formation of greisens and high-temperature quartz veins. The dense net of joints, along which post-magmatic solutions could penetrate the upper layers, caused intensive alteration of the granites. This is proved by the extensive albitization and the formation of greisens in the granites, especially the fine-grained varieties. The ore bodies, and also the zone of greatest alteration of the granites, are typically located near the supposed center of the intrusion (the feeding canal), but in the western block.

In the large- and medium-grained granites the north-northwest and east-northeast joints are very poorly developed, evidently because the tectonic movements that caused them had already become fixed in the radial and concentric joints, still further emphasizing their structure. They were manifested with particular intensity in the radial joints, mainly in those whose strike is close to that of the regional faulted structure. This also explains the great displacement of the individual blocks of granite toward the northwest. In this instance the wedge-shaped blocks of the massif (see Figs. 1 and 2) were displaced to considerable distances horizontally and vertically, thus still more exaggerating the elongation of the massif from north to south. The blocks located along fault I were subjected to the greatest displacement; there the horizontal displacement of one block relative to another was sometimes as much as 1.0 to 1.5 km. Movement along faults running in directions close to the north-south line took place in the later period as well; this is shown by their displacement of the east-west faults and of the ore bodies.

#### SOME FEATURES OF THE DISTRIBUTION OF CERTAIN RARE ELEMENTS IN RELATION TO THE STRUCTURE OF THE INTRUSIVE

Along with the study of the structure of the granite massif, the author has undertaken the task of finding certain laws governing the distribution of the ore-forming elements in the massif, in relation to the geologic position of the individual varieties of granite and their mineral composition and structure.

From what has been said above it can be seen that the massif investigated by the author contains granites intruded at two different stages and composed of three basic varieties: large-grained biotite granite, and medium- and fine-grained strongly porphyritic leucocratic granites. The first two varieties, as has been recognized in investigations of

Kazakhstan [5], belong to the main intrusive phase; the last belongs to the phase of granitic veins.

The granites of the massif described in this article are accompanied by rare-metal (Mo - W) mineralization in the greisens and high-temperature quartz veins. These veins are located mainly in the southern, narrower part of the massif (Fig. 1) near to or directly within the supposed center of the structure, and are nowhere to be traced beyond the limits of the massif; their strike is rarely anything but east-northeast ( $65^{\circ}$  to  $80^{\circ}$ ). The ore bodies, as already mentioned in the previous section, and the supporting molybdenum-wolfram mineralization are associated with specific structures and specific varieties of granite.

Geochemical studies have been made in order to obtain important information on the behavior of the disseminated elements.

Samples for geochemical analysis were taken along profiles separated by definite distances from each other for 200 m across the strike of the massif in the southern, ore-bearing portion; in the northern part, where the granites are represented mainly by large-grained biotite varieties, assays were taken from only three cross-sections, one north-south and two east-west. Samples were taken every 50 m.

Spectrum analyses, and for certain elements both spectrum and chemical analyses, of the assays have produced some very interesting data.

The following regularities, for example, have been found in the distribution of the rare-metal group (Mo - W - Be).

1. The concentration of W, Mo and accessory Be increases from the earlier granites to the later ones -- the fine-grained leucocratic granites whose content of  $\text{SiO}_2$  and alkali is much higher. All three elements are most frequently encountered in granites subjected to secondary alteration. Hence it is evident that the elements of this group have been concentrated in the later differentiates of the granitic magma (the fine-grained granites), and that the greatest degree of enrichment is in the post-magmatic stage.

2. The aureoles of disseminated molybdenum are greatly elongated in the east-northeast direction, conforming with the strike of the greisens and the high-temperature quartz veins. This indicates that the molybdenum was brought in during the later stages in the formation of the intrusive and concentrated in the granites along joints with the same strike as the ore veins and the

greisens. These joints were not always favorable to the formation of ore veins and greisens, but almost always facilitated the circulation of emanations and solutions enriched with molybdenum. Because of the extensive distribution of the east-northeast joints, zones of granites enriched in molybdenum were formed in the same direction.

3. The beryllium is not distributed in any regular zones associated with specific elements of the geologic structure, but there is a noticeable association with the albitized granites. The usual content of Be in these granites is considerably higher than the Clarke amount (the average percentages of the elements in the earth's crust have been taken from A.P. Vinogradov, [3]). In the large-grained granites, which are low in beryllium, the Be content is negligible even in the albitized zones. The degree of albitization of these granites is lower, however.

4. The wolfram content could not be analyzed in all of the assays, especially those from the southern part of the massif, but even in the three profiles along which the assays were taken it was evident that the W concentration was greater in the albitized and especially the fine-grained granites.

The concentration of W, Mo and Be thus probably took place in the later stages of crystallization of the magma, its later differentiates being the most favorable for such concentration.

The elements of the sulfide group -- Pb, Cu, Zn -- behave differently. They are almost uniformly distributed throughout the whole area of the massif and in all the varieties of granite. The lead is distributed in easily distinguished zones along faults with specific strikes, mainly north-northwest. The sulfide elements were evidently introduced along the joints running in this direction -- that is, perpendicular to the joints along which the wolfram and molybdenum were brought in. This especially clear in the southern part of the massif. The distribution of Pb in the northern part of the massif cannot be determined, because of the insufficient number of assays here. The concentration of copper remains fairly constant throughout all the varieties of granite and all the parts of the massif. The concentration of zinc is somewhat higher in the fine-grained granites, but not enough analyses have been made for a complete determination of its distribution.

It may be concluded from the above that the elements of the sulfide group evidently have no connection with the lithologic composition of the granites and, consequently, with the concentrations in specific differentiates from the granitic magma. There are some

indications that they were accumulated later, such as the association of the lead-enriched zones with the fault systems having a north-northwest trend. These are younger than the east-northeast faults with which the molybdenum-wolfram mineralization is associated.

Strontium and barium are more regularly distributed.

1. These elements are most widespread in the large-grained biotite granites of the main intrusive phase. In the vein granites (fine-grained) they are either absent or present in negligible amounts; increases in their concentration are seen only in the endo-contact facies of the granites.

2. The barium is somewhat more widespread than the strontium; according to the analyses, however, the concentrations of both differ sharply in the different varieties of granite. In areas where there is a frequent replacement of the main granites by veins of granite, distinct, often repeated rapid jumps in the concentration curves have been observed.

3. The points of maximum content of Ba and Sr are almost identical, with the exception of the profile passing through the northern block of the granite massif, along which the Sr content is small and the Ba content is almost normal. Barium is almost completely absent in the fine-grained granites and occurs in normal Clarke quantities in the large-grained varieties. The low strontium content in these profiles is apparently a function of the geologic position of the granites, which here occur in the deepest levels.

4. The diminished Ba and Sr content in the fine-grained granites, and even the almost total absence of these elements in places, indicates the decreased importance of the alkali-earth elements in the formation of these granites. Such elements of the alkali group as calcium and sodium, especially the latter, begin to be of considerable importance in the fine-grained granites.

There are much higher concentrations of strontium and barium in the earlier differentiates from the granitic magma than in the later ones. A paper by S.R. Nockolds and R.L. Mitchell [10] deserves mention in this connection; the authors, in analyzing minerals of various generations, find that the Sr and Ba content is considerably higher in the minerals formed earlier than in those of later generation. In the case of potash feldspar they indicate three generations, with a constant decrease in the concentrations of Sr and Ba from the older to the younger varieties. This tendency of Sr and Ba to concentrate in earlier minerals is apparently

the reason for their concentration in the earlier differentiates of the magma.

A number of conclusions may thus be drawn.

1. Strontium and barium are concentrated in the earlier differentiates from the granitic magma, and in the crystallization process enter into the minerals of earlier generations.

2. Molybdenum, wolfram and beryllium are concentrated in the later, more acidic (enriched in  $\text{SiO}_2$ ) and also more alkaline (enriched in  $\text{K}_2\text{O}$  and especially  $\text{Na}_2$ ) magmatic differentiates.

3. The sulfide elements are probably concentrated in the granites during the post-magmatic stage. Because of the limited possibility that these can fit into the silicates in isomorphic form and the probability that other forms of these elements occur in rocks [8], they are not found in any relation to the lithology and are associated rather with structural factors.

#### CONCLUSION

The formation of the structure described above, and especially of the northeastern part of the massif, may apparently be explained only by a study of central intrusions. Such intrusions of Tertiary age were first encountered in Western Scotland and Northern Ireland, where they are widespread. Older intrusions of the central type have recently also been found in the Soviet Union. These include the Khibin alkaline pluton in the Kola Peninsula, described by A.A. Polkanov and N.A. Yeliseyev [4], and the Pambak alkaline pluton in Armenia [6]. The mechanism by which central intrusions are formed was first suggested by E.A. Anderson in 1924 [9]. In 1936 this author published a special paper confirming the correctness of his views by analyses of magmas. In E.A. Anderson's opinion [9], the intense (positive) pressure of the magma produces conical faults accompanied by conical intrusions. If the pressure of the magma becomes lower or negative -- that is, less than the pressure of the overlying strata -- ring-shaped faults accompanied by ring-shaped intrusions are formed. This alternation of magmatic pressure impulses, according to E.A. Anderson, has produced the structure of the central intrusions of Scotland, where the conical and ring-shaped intrusions alternate. The formation of ring-shaped fractures causes the structural block to be dropped, but sometimes this subsidence does not take place.

Without going into the details of the

mechanism of formation of such central intrusions as described by E.A. Anderson and other investigators, it is to be noted that the formation of the intrusion in the district described in this article was somewhat different, although similar in its main features. Here only the conical fractures were formed at the beginning, with the injection of granite porphyries along them during the first stage, in addition to the radial fissures which are usually not filled with material forming dikes. The conical faults might be considered as border thrusts, as observed by I.P. Kushnarev [7] in his investigation of one of the granitic massifs in the Transbaykal area. Later magmatic pressures caused the intrusion of granitic magma, which in all probability followed the same passages as the granite-porphyry magma. The peculiar shape of the intrusive is due to the formation of systems of concentric and radial contraction joints. Additional impulses in the granites themselves caused the formation of systems of concentric (conical) and radial faults conforming to the jointing of the granites; aplite and fine-grained granite magmas were this time injected along certain of the concentric faults. The injection of the magma was facilitated by the formation of normal faults of regional extent, especially of faults with a north-northwest strike; the contraction joints here reflected the shape of the intrusive. This shape in turn was determined by the shape of the folded and faulted structure that preceded it. The lack of ring-shaped faults gave a conical appearance to the entire structure, including the granitic intrusive. This is indicated by the jointing and the series of conical dikes.

The distribution of post-magmatic alterations in the granites (albitization and the formation of greisens, etc.) and of vein rocks, ore veins and separate ore elements indicates that the most favorable area for the manifestation of such phenomena was the central part of the structure. The role of the individual elements of this structure in the concentration of specific types of ore occurrences differed at various stages of its formation.

#### REFERENCES

1. Besplasov, V. F., DZHUNGARSKO-BALKHASHSKAYA GERTSINSKAYA GEOLOGICHESKAYA PROVINTSIYA [THE DZHUNGARA-BALKHASH HERCYNIAN GEOLOGIC PROVINCE]: Vopr. Geol. Azii. Akademiya Nauk SSSR, 1952.

3. Besplasov, V.F., GODROTHERMAL'NO IZMENENNIYE PORODY DZHUNGARO-BALKHASHSKOY GEOLOGICHESKOY PROVINTSII [THE HYDROTHERMALLY ALTERED ROCKS OF THE DZHUNGARA-BALKHASH GEOLOGIC PROVINCE]: Sov. Geologiya, Sb. 51, 1956.
4. Vinogradov, A.P., ZAKONOMERNOSTI RASPREDELENIYA KHIMICHESKIKH ELEMENTOV V ZEMNOY KORE [THE LAWS GOVERNING THE DISTRIBUTION OF CHEMICAL ELEMENTS IN THE EARTH'S CRUST]: Geokhimiya, no. 1, 1956.
5. Yeliseyev, N.A., STRUKTURNAYA PETROLOGIYA [STRUCTURAL PETROLOGY]: Izd. Leningr. Universiteta, 1953.
6. Koptev-Dvornikov, V.S., K VOPRUSO O NEKOTORYKH ZAKONOMERNOSTYAK FORMIROVANIYA INTRUZIVNYKH KOMPLEXOV GRANITOIDOV [THE PROBLEM OF CERTAIN LAWS GOVERNING THE FORMATION OF GRANITOID INTRUSIVE COMPLEXES]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 4, 1952.
7. Kotlyar, V.N., PAMBAKSKIY KOMPLEX SHCHELOCHNYKH POROD [THE PAMBAK COMPLEX OF ALKALINE ROCKS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 2, 1945.
8. Kushnarev, I.P., OSOBNOSTI TRESHCHINNOY TEKTONIKI DVUKH RAZNOVOZRASTNYKH MASSIVOV GRANITOIDOV [SOME SPECIAL FEATURES OF THE JOINT STRUCTURE OF TWO GRANITOID MASSIFS OF DIFFERENT AGES]: Tr. Instituta Geol. Nauk, Akademiya Nauk SSSR, Vyp. 162, 1955.
9. Tauson, L.V., IZOMORFIZM I RASPREDELENIYE REDKIKH ELEMENTOV V GORNYKH PORODAKH [THE ISOMORPHISM AND DISTRIBUTION OF RARE ELEMENTS IN ROCKS]: Sb. Vopr. Mineralogii i Petrografii, t. 1, 1953.
10. Anderson, E.M., THE DYNAMICS OF FAULTING AND DYKE FORMATION WITH APPLICATION TO BRITAIN: Edinburgh - London, 1951.
11. Nockolds, S.R. and R.L. Mitchell, THE GEOCHEMISTRY OF SOME CALEDONIAN PLUTONIC ROCKS: A STUDY IN THE RELATIONSHIP BETWEEN THE MAJOR AND TRACE ELEMENTS OF IGNEOUS ROCKS AND THEIR MINERALS: Trans. Roy. Soc. Edinb., V. 61, p. 2, 1948.

Institute for the Study of the Mineralogy,  
Geochemistry and Crystallochemistry  
of Rare Elements of the U.S.R.  
Academy of Sciences  
Moscow

Received December 27, 1957

# THE METALLOGENY OF ORE DISTRICTS

by

Ye. T. Shatalov

This article stresses the great importance of a detailed study of the metallogeny of ore districts. The author describes the basic principles and possibilities in the development of methods for such study and for the construction of metallogenic and forecasting maps of ore districts.

\* \* \* \* \*

## I. INTRODUCTION

Metallogeny, one of the newer branches of geologic science, was originated and developed by the present generation. The direction of the great volume of geologic prospecting work done in the Soviet Union requires a scientific foundation; thus, the problems involved in the study of the laws governing the distribution of ore minerals in connection with geologic structure have always attracted the attention of geologists including such distinguished U.S.S.R. scientists as V.A. Obruchev [18] and A. Ye. Fersman [27].

The pioneers in the study of metallogeny in the Soviet Union are S.S. Smirnov and Yu.A. Bilibin, in studying a number of problems of regional metallogeny and of the metallogeny of tin and gold, the two scientists have laid the foundations for the theory and methods of metallogenic investigation.

In recent years, these investigations have achieved widespread importance, both in scientific research and in industrial organizations. The problem of laws governing the distribution of chief ore minerals in the earth's crust as a basis for predicting their occurrence within the territory of the U.S.S.R. has become one of the most important of our time.

---

A report to the Scientific Council of the Institute for the Study of Geology, Petrography, Mineralogy and Geochemistry of Ore Deposits of the U.S.S.R. Academy of Sciences on October 28, 1957.

## II. DETAILED METALLOGENETIC INVESTIGATIONS

In drawing up and developing the program of investigation of the problem of "The Laws Governing the Distribution of the Chief Ore Minerals", three basic types of predictions were established in relation to the amount of detail shown on the final metallogenic and forecasting maps.

1. Regional predictions based on the study of metallogenic provinces and zones; these are drawn to show potential ore-bearing areas on the order of an ore district, in order to make further more detailed investigations.

These investigations are usually made on the basis of geologic maps with a scale no greater than 1:500,000, which will thus also be the scale of the resulting metallogenic maps.

2. "Medium-scale" metallogenic investigations and forecasts, or the study of the metallogeny of ore districts to determine the probable disposition of the ore concentrations and fields, and sometimes individual deposits, on the basis of geologic surveys on scales of 1:50,000 - 1:25,000 for the most part, and less often of 1:200,000 - 1:100,000.

3. Large-scale predictions to determine the prospects for discovering both the area and the depth of ore fields and deposits, on the basis of large-scale mapping (1:10,000 or greater) and of special studies made by prospecting.

The general principles of metallogenic analysis and the methods of constructing maps that have been developed in the All-

Union Geologic Institute (VSEGEI) [19] apply mainly to small-scale survey maps (1:2,500,000 - 1:500,000) and in part to medium-scale (1:200,000) maps. The latter scale is essentially the lower limit for regional metallogenic work, and makes it possible to define the local structures in order to make further detailed geologic prospecting studies, mainly on the scale of 1:50,000 - 1:25,000.

The VSEGEI methods may be successfully used in discovering metallogenic belts and provinces and structural-metallogenic zones and in making predictions for areas on the order of an ore district which are also distinguished in systematic geologic surveys on a scale of 1:200,000.

But the most important in the direct discovery of occurrences and deposits of ore minerals are detailed geologic surveys on scales of 1:50,000 and 1:25,000. These are usually made in conjunction with a certain amount of prospecting work, after which recommendations are made for explorations and prospecting in strictly local, small areas measurable in square kilometers or at specific points. This stage of work thus encompasses the transition from making suggestions for the further exploration of certain areas (which are usually easy to make) to recommendations for the prospecting of specific objectives.

Hence the present need to support this work of applied geology by a scientifically based methodology of metallogenic investigations that might, by supplementing and enlarging the scope of the detailed geologic surveys, be an essential aid in predicting the possible location and localization of mineralization.

It must also be stressed that the methods of regional metallogenic analysis developed by VSEGEI cannot be applied directly to the detailed metallogenic investigation of ore districts: as mentioned above, their "permissible validity" ends at the scale of 1:200,000. Moreover, the actual application of these methods to individual regions -- the transition from the system in time to space -- has shown that they are by no means universal (something which their authors have always stressed) and cannot encompass the whole variety of natural occurrences. The circumstance should also be kept in mind that all the stages of development are not represented in all metallogenic provinces: the beginning and early stages predominate in some (the Urals), the middle and late and final stages in others (the eastern Transbaykal area), or the middle and late with a poor representation of the final stages (the northeastern

U.S.S.R.), or the initial, early, late and final with the omission of the middle stages (in Tuva). Thus there is no doubt of the existence of still unexplained "provincial" peculiarities and differences in the course of geologic processes in time which are not envisioned in the VSEGEI system. The approach to the study of the metallogeny ore districts that are determined by the more rigid historical development and position in space of a specific structural and metallogenic zone must differ from that used in regional metallogenic analysis.

Recent years have seen the appearance of other trends in both regional and more detailed metallogenic investigations; metallogenic maps have come to be constructed by a considerably wider group of scientific and industrial organizations. One example of such regional work is the metallogenic and forecasting maps of Central Kazakhstan drawn up under the direction of K.I. Satpayev by a large association of geologists in the Geologic Institute of the Academy of Sciences of the Kazakhstan SSR and the geologic organizations of Kazakhstan.

Metallogenic investigations of individual ore districts and zones are also being made by a number of geologic institutes in academies of sciences of other republics and by the industrial organizations of the Ministry of Geology and Conservation of Mineral Resources of the U.S.S.R. At the present time, for example, metallogenic and forecasting maps are being made of Georgia and of individual rayons in the Urals, Central Tadzhikistan and Darvaz, the Kurama ore subzone (Uzbekistan), the Angara-Ilim district and the Yenisey ridge, the Noril'sk district, the Ol'ga-Tetyukhe (Primor'ye) district and many others. It is noteworthy that the majority of these investigations are for the purpose of constructing metallogenic and forecasting maps on a scale of 1:200,000, but no greater.

Detailed metallogenic investigations have also been undertaken by the Institute for the Study of the Geology, Petrography, Mineralogy and Geochemistry of Ore Deposits of the U.S.S.R. Academy of Sciences (IGEM: Ye.A. Radkevich, Ye.T. Shatalov). These efforts are based on the further development of S.S. Smirnov's and Yu.A. Bilibin's ideas on metallogeny, as applied to "medium-scale" metallogenic studies and predictions, along with the construction of detailed metallogenic maps mainly on a scale of 1:50,000 - 1:25,000.

Ye.A. Radkevich has introduced the concept of the most characteristic "type" ore districts, in regard to their endogenetic mineralization, and by her investigations in

collaboration with N.A. Belyayevskiy in the Primor'ye has begun their study. Ye.A. Radkevich has stressed the fact that very detailed "saturation" by an "ore load" is one of the most important features of the metallogenic maps of ore districts.

Even a brief survey and enumeration of the metallogenic investigations presently being made by scientific and industrial organizations will clearly reveal the tendency toward increased detail and larger scale as compared to regional maps; this is natural in view of the great practical problems with which geologists are confronted.

These tasks will be carried out more and more frequently under the complex conditions of hidden districts and of concealed ore fields, deposits and blind ore bodies. S.S. Smirnov has more than once stressed the fact that the most easily accessible and simply detected deposits of ore minerals have already been found, and has pointed out the need for establishing new methods of discovery. It is quite reasonable to think that the detailed metallogenic investigation of ore districts will occupy an appropriate place among such methods.

The development of effective methods of studying the metallogeny of ore districts must rely on theoretical investigations; it should be emphasized that this may be accomplished by the numerous works produced by Soviet scientists, including the workers in the IGEM of the U.S.S.R. Academy of Sciences.

Serious investigations of the connection between igneous activity and hydrothermal mineralization, of the nature of hydrothermal solutions and the disposition of the ores in them and of the theory of metasomatic processes have been made by A.G. Betekhtin, D.S. Korzhinskiy, O.D. Levitskiy and others (1953). Much interesting information on igneous activity and the mineralization genetically and otherwise associated with it may be found in papers by Kh.M. Abdullayev, G.D. Afanas'yev, M.B. Boro-dayevskaya, V.S. Koptev-Dvornikov, I.G. Magak'yan, M.G. Rub, M.A. Favorskaya, F.K. Shipulin and others. Naturally their treatment of certain aspects of these complex and sometimes far from clear geologic processes will differ and sometimes provoke sharp disputes; nevertheless another aspect must be stressed, the fact that present-day investigations have a different approach in principle from those made earlier. Petrochemistry, for example, has moved from a study of the main component parts of rocks to detailed study of the value of the rare and disseminated elements

and accessories as petrochemical criteria of the connection between igneous rocks and mineralization. Relationships in age, which had earlier been determined only by geologic observations, have now been made more accurate by the methods of determining the absolute ages of rocks (G.D. Afanas'yev). Such examples could be multiplied.

A very fruitful and important development for the investigation of the metallogeny of ore districts has been the study of the structures of ore fields (F.I. Vol'fson, V.M. Kreyter, L.I. Lukin, A.V. Pek, A.V. Korolev and others). Detailed studies of the ore material itself have been made by A.G. Betekhtin, T.N. Shadlun and others. I.I. Ginzburg, finally, has established a whole new trend with his study of the erosion of the earth's crust and other exogenetic processes; he has designated the theoretical basis of the geochemical methods of prospecting for nonferrous and rare-metal ores, and for the construction of geochemical maps.

The results of all these and many other investigations, along with the valuable information contained in the numerous papers by geologists in industry, which are of extremely great importance, are a reliable basis for the growth of detailed metallogenic investigations of ore districts.

### III. THE BASIC PROBLEMS AND PRINCIPLES IN THE METALLOGENIC INVESTIGATION OF ORE DISTRICTS

The metallogenic investigation of ore districts involves a complex of geologic operations designed to discover the laws governing the formation and distribution of deposits of ore minerals throughout these areas -- in other words, to determine the geologic position of the deposits.

An ore district is, in the last analysis, an ore-bearing area that forms part of a metallogenic belt, a structural-metallogenic zone or some other unit (province, region) with common geologic features and the development, as a rule, of specific ore formations or types of industrially important mineral deposits of one (the leading) or several metals. These deposits are usually associated genetically and are close to each other in age; they are developed against a background of small and medium-sized ore occurrences and (or) regional scattered mineralization.

Ore districts are usually separated from each other or from other ore-bearing zones by non-ore-bearing or weakly mineralized areas; consequently they are distinct both geographically and in respect to their in-

dustrial and economic importance. Examples are the Yana-Adychan tin-ore district in the Northeast, the Tetykhe polymetallic district in the Primor'ye, the Lower Tagil' platinum district of the Urals, and many others.

The ore district is thus a part of a regional ore-bearing structure, and the general conditions of its formation are determined by the geologic processes that have formed this structure. Hence it is quite obvious that these general conditions must be ascertained through the methods of regional metallogeny. The connection of a given ore district with one regional structure or another and with the stages of its development (such as initial and early, middle and late, late and final) will to a considerable degree determine the specific features, or the type, of the ore district.

The ore mineralization of a given district may be endogenetic, exogenetic or metamorphogenetic; this will frequently also determine the type of the ore district and the significance of the combination of various factors in relation to the distribution of mineralization; the methods of investigation will also vary.

In districts with endogenetic mineralization, for example, the most important factors will be magmatic, structural and lithologic in determining the formation and disposition of the mineralization and the occurrence of the given ore formations and genetic types of deposits, in addition to certain exogenetic criteria and geophysical and other data that facilitate the finding of the endogenetic deposits. In ore districts of various types these factors will appear specifically in relation to the composition of the igneous rocks, the depth of the intrusion, the process determining the presence of mineralization (magmatic segregation or eliquation, pegmatitic, hydrothermal, etc.) and which to the first approximation determines the place and the relative time of formation of the deposit, and the other properties of igneous activity.

Districts composed of sedimentary terrigenous rocks or carbonate deposits, or of volcanogenic-sedimentary or extrusive series, will have their own peculiar characteristics. All these peculiarities, structural (including the morphology of the igneous bodies) and otherwise, will determine the type of the ore district containing the endogenetic mineralization and thus also the complex of metallogenic investigations.

In districts with exogenetic and metamorphogenic deposits other factors will be of primary importance, and the methods of investigation will consequently be different.

The basic features of the metallogenic study of ore districts will result from the degree of detail of the investigation, the scale of the metallogenic maps, and the final objectives of the study -- the distinction among the various ore districts, by means of individual externally unconnected ore occurrences and by favorable geologic indications, of the probable locations of the ore concentrations and fields, and sometimes of individual deposits or, in other words, "medium-scale" predictions.

The metallogenic investigation of ore districts must successively develop general concepts regarding the geologic position of the mineralization discovered by the methods of regional metallogeny, and refine these concepts by the application of more detailed methods of investigation. Some of these are presented below.

This type of metallogenic study is distinguished by a broader scope than the study of ore fields and deposits (large-scale predictions) and by the thorough investigation of all the properties of the localization of mineral formation in the area of an ore district as a whole; this enables one to study all the occurrences of mineralization (post-magmatic alterations in the host rocks, outcroppings of ores and deposits) in their possible association with igneous rocks, and to reveal the zonality of the ore formation (more often horizontal than vertical, to be determined by a detailed study of the mineralization of prospected deposits). In studying the relatively small area of an ore field this very important aspect of metallogenic investigations, especially in the case of hydrothermal deposits, is usually not touched upon.

One of the fundamental differences between the metallogenic investigation of ore districts and more detailed studies (in known ore fields) is the study and establishment of potential areas for the finding of mineralization, often by indirect evidence such as the morphology of igneous bodies, aureoles of primary mineralization, favorable structural features, the presence of shielding strata, etc. -- that is, the finding of indications suggesting the presence of new, concealed ore fields and deposits.

It is both natural and necessary that metallogenic investigations of ore districts should make use of the achievements of the theory of ore formation, applying them, however, to the purpose of finding out the distribution of ore minerals in space, and not only to the genetic aspects of the processes of ore formation.

An important final goal of the metallo-

genic investigation of ore districts is the production of metallogenic and forecasting maps. Metallogenic maps must have a basis in geology which will support the revelation of the regular features in the distribution of the ore mineralization, as well as exhaustive information on all ore occurrences -- that is, a detailed "ore load"; this distinguishes metallogenic from ordinary geologic maps. The basic conclusions and recommendations are shown on forecasting maps. The regular features that have been discovered should be clear from the content and the means of depicting the data on metallogenic and forecasting maps.

The above-enumerated groups of factors and criteria for the metallogenic investigation of ore districts will be considered in greater detail below. In conformity with the work being done by the IGM of the Academy of Sciences of the U.S.S.R., the discussion below will be concerned with districts containing endogenetic mineralization, associated mainly with Paleozoic and younger igneous activity.

S.S. Smirnov and A.G. Betekhtin have distinguished groups of hydrothermal deposits according to their connection with igneous activity.

1. There is no doubt of the direct connection of this group with igneous bodies; to this class belong the igneous deposits proper.

2. In this group there is no doubt of the general genetic or physical association with definite igneous complexes, but this must be proven in each individual case. This group encompasses pegmatite, pneumatolytic and skarn deposits and some hydrothermal deposits (mainly hypothermal).

3. Here the connection with definite igneous formations is not clear. This group includes another part of the hydrothermal deposits, mainly mesothermal and epithermal.

4. In the last group the attribution of the deposits to the category of those of igneous origin requires proofs and special investigations, as, for example, in the case of the so-called "telethermal" deposits.

The igneous, structural and lithologic factors and the mineralogic and exogenetic criteria do not always have the same significance in the study of the metallogeny of districts containing deposits belonging to these very different groups. From the very definition of the groups it is obvious that the importance of igneous factors in establishing the disposition of the mineralization

decreases sharply from the first to the fourth groups. It is therefore necessary to establish reliable structural, lithologic and other criteria in forecasting the locations of deposits in the third and fourth groups and to find more definite proofs than those known at present of the connection of deposits of these groups with igneous activity.

Igneous factors. The establishment of a genetic connection between mineralization and igneous activity presents great difficulties because of the lack of unequivocal proofs of such a connection in many types of deposits.

In the broadest sense, the connection between igneous activity and mineralization is expressed in S.S. Smirnov's well-known concept of the existence of intrusive (or igneous) complexes with special kinds of ore-bearing; this differs in principle from A.F. Waddington's views on the connection between various ore deposits and definite stages and types of differentiation from the primary magma. The idea of specialized ore-bearing intrusive complexes was later developed by Yu. A. Bilibin, who explained the connection between intrusive complexes and mobile ore belts at various stages of development. But these ideas, which are fundamentally correct, can be applied to regional metallogenic constructions of the characteristics of belts and provinces and of structural-metallogenic zones to produce only general conceptions of the role of igneous activity in an ore district as a part of these units of area. Yu. A. Bilibin himself has called attention to the various kinds of ore-bearing to be found in individual members and phases of an intrusive complex, the irregularity of their occurrence in space and the different connections between them and the type of mineralization. The study of the nature and laws of these differences and the establishment of less equivocal criteria for the connection between mineralization and igneous activity under given conditions are basic tasks in the metallogenic investigation of ore districts; in a number of cases this is difficult because of the still insufficiently developed state of certain questions in the theory of petrology and ore formation.

Under these circumstances it is an extremely complex task to find the criteria for comparing the ages and depths of ore formation and igneous intrusion during the process of their development; the following are required in order to obtain such criteria.

1. Study of the special forms of ore-bearing intrusions related to the latest,

acidic differentiates of complex, multiphase intrusive complexes (for example, M. G. Rub's and M. A. Favorskaya's investigations in the Primor'ye and V. T. Matveyenko's in the Northeastern U.S.S.R.).

2. The collection and analysis of data relating to transitional forms between igneous rocks and ore formations, such as greisens, pegmatites and contact-metamorphic rocks).

3. Comparison of the "depth" of ore deposits and intrusive bodies in regard to a number of geologic (such as assimilation) and other indications, including the mineral thermometer; this comparison is very complicated because of the existence of "tele-scaled" deposits and the possibility that low-temperature deposits near the surface may be associated with deep-seated rocks.

4. Establishment of the age of the mineralization and the intrusive rocks both by the usual geologic means and by the determination, wherever possible, of the absolute age of metasomatic and hydrothermal formations; this method has turned out to be one of the most effective for deposits of the third group.

5. Study of the isotopic composition of the elements in the rocks of the separate intrusive phases and the ore deposits associated with them (this may be useful in studying deposits of the third group).

It is also important to establish the connection between mineralization and rocks having definite petrographic compositions and the petrochemical criteria of this connection by studying the chemical composition and finding out the typical elements for various intrusive phases, vein rocks and ore formations, and by a comparison of the accessory elements (including rare and disseminated elements), as M. G. Rub [21] has done in investigating the Prikhankay district of the Primor'ye. Petrochemical criteria are important for the deposits of the first and third groups, and will produce especially valuable data in studying deposits of the third group.

In the case of proper igneous deposits (the first group), a study of the compositions of the intrusives that form the matrix of the ores and of the conditions under which the ore components in them were separated (segregation during crystallization, eliquation, residual melts), as well as of the morphology of the intrusive bodies, is of decisive importance.

It is important to study the statement made by A. G. Betekhtin that previous ideas

on "forbidden" associations of metals for magmas of basic and acidic composition are not entirely correct. It is well known, however, that the concept of "forbidden" associations is supported by practical experience and is of great value in prospecting for industrial concentrations of metals -- to a considerable degree it is the determining factor in a number of serious practical recommendations. One must also keep in mind the intensity of the mineralization and the possibility that small quantities of "forbidden" metals from later processes may have been carried in.

Particular attention must be given to determining the occurrence and the physical connection of the intrusives and associated deposits with specific structural zones and levels. In each individual case it is important to find the relationship of the ore formation to the roof or apex of the intrusive body, and also the association of dikes, vein-rocks and ore bodies with the primary structure. Such detailed structural and morphologic investigations, in which geophysical methods must be widely used, are one of the characteristic differences between medium-scale and regional metallogenic work; they are of particular value for deposits of the second group.

Contact aureoles and endo- and exocontact alterations in intrusive bodies play a great role in revealing their morphology; a comparison of these alterations with metasomatic alterations around the ores may prove useful in establishing the connection between the mineralization and the intrusions (in the case of deposits of the third and second groups). Valuable information for this purpose and for the prediction of the locations of ore fields and deposits (of the third, and possibly the fourth, groups) which are not exposed to the surface may be obtained from a study of primary aureoles of disseminated mineralization.

There are some peculiar, but sometimes from a practical point of view extremely important ore districts in which the mineralization is physically associated with small intrusions and dikes. Examples of such districts are the Eastern Transbaykal, where minor intrusions are one of the factors controlling the polymetallic mineralization, and the Northeastern U.S.S.R. with its zones of gold-bearing, hydrothermally altered, albitized "pre-granite" dike rocks, etc. A thorough study of all aspects of the occurrence, composition and interrelationships of the intrusive and the mineralization is necessary in this case for the same reasons as in the case of multiple intrusive complexes and phases.

This raises a number of important questions which sometimes involve basic problems of petrology, such as the independence of minor intrusions and dike formations as separate phases in the development of a tectonic and igneous cycle, or their closer association with batholiths or extrusives; or the time of injection of the minor intrusions and dikes in relation to the intrusives and the number of phases; or the interrelationships of these phases with the time of the mineralization; or, finally -- and this is scarcely the least important -- the possible genetic association of the mineralization with these rocks.

Not all investigators agree with the definition of the concept of "minor intrusions" and their role in the development of igneous processes and mineralization (Kh. M. Abdullayev, M.B. Borodayevskaya, F.I. Vol'fson, V.S. Koptev-Dvornikov, and F.K. Shipulin), but the ever-increasing deep interest in these serious questions is a guarantee that in a number of cases minor intrusives and dikes will be a reliable criterion for establishing their paragenetic association, at least, with the mineralization; this is especially important for deposits of the third group.

For certain ore districts valuable results may be obtained from similar detailed investigations of the subvolcanic rocks physically associated with various ore deposits (as in the Primor'ye and the Northeastern U.S.S.R.).

The question of the occurrence of ore in extrusive complexes proper is still far from solved. In regard to the metallogenic role of terrestrial extrusive rocks, there are data only on their physical connection in certain districts with deposits of gold, silver, tin and mercury that are close to the surface. Chalcopyrite deposits have been found to be widely associated with the rocks of spilitic-ceratophyric and extrusive sedimentary formations such as those of the eastern slope of the Urals.

It is very important in making prognoses to study erosion as a factor in the degree of preservation of the deposits and in the metallogeny of the ore district which may be discovered and observed at the present time. Determination of the possible depths of the formation and the locations of the mineralization must, naturally, be made on the basis of the igneous factors examined above, with a critical consideration of the data on erosion.

Structural and lithologic factors are of extreme importance in discovering the laws that govern the physical distribution of the

ore formation. In contrast to the igneous factors, which determine the origin of the primary source of mineralization, the structural and lithologic factors to a very great degree affect the localization of the mineralization and the creation of enriched concentrations. The role of the structural and lithologic factors increases greatly in importance in studying the placement of deposits of the third and fourth groups, for which they are the leading criteria, although they are also important for the second group.

Among the structural factors proper one may distinguish factors of the first order, which determine the origin of folded structures in the geosynclinal flexures and uplifts and on the edges of platforms -- the structural-metallogenic zones or ore belts. In addition there may be a formation of structural levels whose role in the localization of the mineralization will vary. In V.A. Peyve's opinion, regional and often deep, long-active faults may be of particular importance.

Structural factors of the first order thus determine the type of the ore district and, to the first approximation, influence the distribution of the igneous bodies, ore zones, ore fields and deposits within the district, and must be studied from this point of view.

Folded structures and disjunctive dislocations of the second order, which are combined with the folding and located within it, have an exceedingly important and sometimes (together with the lithologic factors) decisive significance in the direct localization of the mineralization and the formation of ore fields and deposits -- that is, for the basic aims of "medium-scale" predictions. The study of folded structures of the second order is especially important for districts with deposits belonging to the third and fourth groups, since it will often produce criteria for determining the distribution of the ore bodies, but it is also of great importance for deposits of the second group.

F.I. Vol'fson [10] has noted some of the main structural geologic positions of ore fields, which tend to occur in favorable tectonic structures of the second order -- bendings of the axial planes of anticlines, large tectonic faults, places in which faults branch out, areas where there is a development of fissures that determine the main tectonic faults, points of intersection of faults, and a number of others; the detailed occurrences of many igneous rocks often depend on these very structures. In the Primor'ye, Ye. A. Radkevich and I.N. Tomson have established the great importance, in the formation of ore fields, of highly fissured zones which are fixed in the

upper structural level by deep-seated faults.

Lithologic factors -- the chemical, physical and mechanical properties of rocks -- are also among the most important in determining the characteristics of ore districts as a whole, but they play a still greater role in the recognition of the physical positions of ore fields and deposits, especially of the third and fourth groups. Along with the structural factors, they often determine the paths of the ore solutions and the possible localization of the mineralization, both as a result of the favorable composition of the rocks and in the presence of shielding horizons.

Numerous examples of the importance of structures of various orders and of the lithology in the formation of ore fields and deposits are cited in the many papers published by the association of scientists in the structural workshop of IGEM, in "Basic Problems in the Study of the Structures of Ore Fields and Deposits", compiled under the direction of F.I. Vol'fson and L.I. Lukin; much valuable information on this problem is also contained in papers by V.M. Kreyter [15], V.I. Smirnov and other investigators. It can only be emphasized that the study of structural and lithologic factors will be especially profitable if, in addition to the usual geologic methods, geophysical methods are employed in studying the structures, densities, fractures, porosities and other physical and mechanical properties of rocks.

Mineralogical criteria may be very important not only in defining the ore formation and the genetic type of the deposits, but also in discovering such features of the mineral composition of the ore as will indicate a possible association with igneous rocks and also the depth of the mineralization, the horizontal zonality and much other information that is useful in predicting the location of deposits of all four groups.

An ore formation, in S.S. Smirnov's view, is understood as a group of deposits having constant mineral associations and formed under similar geologic conditions; this will also determine their significance for metallogenic investigations of ore districts. In more detailed work on individual deposits and ore fields, including the finding of the vertical zonality of the ore and its distribution in depth, a deeper study of the typical mineral associations, and especially of the paragenetic relationships of the minerals, is made.

In order to use this very important criterion one must find and describe all the actually specific ore formations in relation

to the geologic conditions that determine the basic types of ore districts; and in so doing one must not go into excessive detail. Ye. Ye. Zakharov, [12], for example, distinguishes more than 200 formations, among them about 90 endogenetic metalliferous and non-metallic deposits. F.I. Vol'fson [8] also presents valuable data on the generation of ore formations.

I.G. Magak'yan's paper [16] is also of interest in this respect. On the basis of the paragenetic associations of minerals and elements and the geologic circumstances of their formation, he distinguishes 27 main families of endogenetic ores (the term "ore family", as used by Magak'yan, has practically the same meaning as "ore formation").

The practical value of ore formations in metallogenic analysis is known from the example of the sulfide-cassiterite formation, inasmuch as by distinguishing it and accurately defining its geologic position and mineralogic characteristics S.S. Smirnov was able to direct the prospecting for tin along other lines and in a short time to make a decisive re-evaluation of the Soviet Union's tin resources.

Mineralogical criteria may also produce great results in studying the general background of regional disseminated mineralization and the formation of aureoles of primary disseminated mineralization, whose presence is one of the basic indications of ore districts.

The value of mineralogical criteria is unfortunately out of proportion to the amount of work done in mineralogy in connection with these metallogenic aims -- the quantity is still negligibly small.

Exogenetic evidence may have to be used to discover the laws governing the development of endogenetic mineralization, and in numerous cases provides one of the basic indications of the presence of endogenetic ore formation (zones of oxidation, crusts of weathered matter, aureoles of secondary dispersion, placer deposits, etc.). The value of exogenetic criteria differs for the so-called "open" and "hidden" (by thick unconsolidated sediments) ore districts.

Many valuable suggestions for the use of exogenetic criteria to recognize endogenetic mineralization have been made by I.I. Ginzburg in his work, An Attempt to Develop a Theoretical Basis for the Methods of Geochemical Prospecting [11], which essentially contains both the scientific basis for the use of exogenetic criteria and geochemical surveys for the metallogenic investigation of ore districts.

I.I. Ginzburg has stressed the importance of certain elements and minerals as geochemical indicators suggesting the presence of endogenetic deposits of a specific origin. Investigation of these indicators and their geochemical correlation must be done in association with the others -- metallogenetic and geologic -- noted above. This pertains above all to the study of primary aureoles of disseminated mineralization, which has many typical indicators.

The method of separation of the elements associated in a typomorphic complex may, according to I.I. Ginzburg, be used to distinguish syngenetic aureoles of primary disseminated mineralization from epigenetic (introduced by different post-magmatic processes).

Proper exogenetic criteria include hypergenic indicators -- weathering crusts containing oxidation zones, various secondary aureoles of disseminated mineralization, schlich aureoles (eluvial, deluvial and alluvial), placer deposits and others, which may yield valuable information in discovering the type features of the ore district and the characteristics of the mineralization in it. The nature of the exogenetic criteria is determined by climatic, topographic, hydrogeologic and biologic factors, the original composition of the rocks in situ and the tectonics of districts with different geologic and geomorphologic features, which must be studied to the required extent.

Exogenetic criteria may be used for all four groups of deposits, although they are more valuable in the case of deposits of the third group and less so for those of the fourth and second groups.

The study of exogenetic criteria is closely associated with geochemical surveys and may be made by the use of such methods and the construction of geochemical maps. A determination of the content and distribution of the various metals in all the rocks making up the district -- extrusive, sedimentary and unconsolidated sediments -- will be of special value in establishing the general "background" or "contamination" of the district by metals and picking out the areas with increased metal concentrations.

The most immediate task in studying exogenetic criteria is to work out the methods and scope of the investigations of these criteria, so as to construct metallogenetic and geochemical maps on scales of 1:50,000 and 1:25,000 and to make medium-scale predictions.

#### IV. SOME QUESTIONS OF METHOD AND THE CONSTRUCTION OF METALLOGENETIC AND FORECASTING MAPS

Metallogenetic investigations of ore districts (medium-scale) amount essentially to a detailed geologic study of all the factors and criteria that determine the presence and locations of the mineralization, as well as of the ore occurrences and deposits themselves -- that is, to a particular kind of specialized geologic "ore" survey. These investigations must be based on geologic maps on a scale of 1:50,000 or 1:25,000, supplementing them with data showing the connections between the ore formation and the geologic structure of the district.

A universal system of methods encompassing the structural peculiarities of all the various types of ore districts is not recommended and not required. In each particular case one must choose the combination of investigations which will produce the best results under the conditions of the geologic position of the mineralization in the given district. This combination of methods should be studied for each type of ore district and recommendations made for its use.

Two basic cases may be distinguished in carrying out medium-scale metallogenetic investigations: a) ore districts that have already been studied earlier and contain known ore fields and deposits which have often been exploited; b) ore districts that are little studied or which have been found to contain favorable geologic indications, in which only ore occurrences or, at best, single deposits are known. The methods used in investigating these two cases will differ.

In "old" districts the investigation must start from known points, by expanding the areas of the ore fields, discovering new ones situated in similar geologic conditions, studying the distribution of the mineralization in depth, finding concealed ore fields and deposits, usually in the vicinity of the known ones, etc. The metallogenetic investigations may here rely on the established connections between the mineralization and given rocks or structures, merely deepening and expanding them; in a number of cases they will merge with large-scale investigations.

In little studied or in potential ore districts, such already established information for all practical purposes does not exist and must be produced, often on the basis of general geologic premises or indirect evidence. Here the role and importance of predictions increase considerably; forecasts become more difficult and must be built

upon detailed analysis of geologic maps on a scale of 1:50,000 - 1:25,000 with appropriate supplementary "ore" investigations, and sometimes on daring scientific hypotheses.

The results of metallogenic investigations are reflected on maps -- geochemical, geophysical, metallogenic and forecasting (and perhaps certain others, if necessary) -- constructed on the basis of detailed geologic maps (on a scale of 1:50,000 or larger) and a supplementary study of the material from the metallogenetic point of view. It is totally unnecessary to construct every kind of map for each district, since the number and types of the maps will depend on the group of methods applied and the concentration of information plotted, both geological and special. In the present author's opinion, only two maps are required -- metallogenic and forecasting -- but these may be combined in one if sufficiently indicative symbols are used.

Some remarks follow on the essential nature of these maps.

A metallogenic map gives a clear picture of the connections found between the mineralization and igneous activity, structural and lithologic factors, and mineralogical and exogenetic criteria. These associations must reveal themselves in an examination of the map itself and must thus be shown on it in one form or another; the basis of the favorable criteria and indications is set forth in an explanatory note.

The geologic underlying basis of the map must emphasize the criteria and evidence that determine the geologic position of the ore mineralization under the conditions of the given district.

The actual "ore load" of the map must be exhaustively complete, plotting all the deposits and ore occurrences produced both by post-magmatic processes, including hydrothermal alterations around the ores and aureoles of disseminated primary mineralization, and by specified exogenetic processes.

The scale of the map will be determined by the most detailed existing geologic base and the nature of the supplementary metallogenic investigations; this is usually 1:50,000 or 1:25,000, sometimes with larger scale (1:10,000 or greater) insets for particular parts. Such scales permit a great amount of detail in showing the "ore load", especially in retaining the morphology of the ore bodies and occurrences, with sometimes only a small distortion of the magnitude. A scale of 1:200,000 is not

practicable for this type of investigation and may be used only in making overall metallogenic survey maps of ore districts.

A geochemical map, which is drawn from specialized geochemical surveys and metallogometric testings, should show the distribution and concentrations of the individual elements in various rocks and sediments, taking account of the geologic structure. I.I. Ginzburg believes that a general geochemical map should show only the leading elements or individual groups of elements associated by a common origin; such a map should be constructed along with the metallogenetic map and, if possible, combined with it. I.I. Ginzburg stresses the expediency of drawing geochemical maps generally, without reference to their purpose, and recommends that the elements characterizing the complex or process under consideration be studied and shown on maps.

Geophysical maps, in addition to the required amount of "geophysical" factual data, should have a background of geology and data showing the geologic nature of the investigations -- anomalies that directly indicate the possible presence of ore minerals (magnetic, sulfide, including pyritic, and radioactive), the boundaries of bedded rocks and sediments established on the basis of their physical properties, the exposed details of folded structures, and data on the possible depths of occurrence of intrusive bodies, dikes, veins, ore deposits, tectonic faults, and other matters obtained by various geophysical methods.

The geologic results of geophysical investigations may almost always be shown directly on metallogenic maps, without constructing special geophysical maps.

Forecasting maps make up the final stage of metallogenic investigations, with the purpose of distinguishing the areas and objectives that have the greatest prospects for a given metal or group of metals. Forecasting maps may be drawn on overlays and placed over the metallogenic map, or else as independent maps in themselves; in the latter case they must contain data to show the geologic position of the ore mineralization and the basis of the selection of favorable areas.

The metallogenic investigation of ore districts involves various different branches of geology, so that its basic principles and methods must be evolved collectively, both by searching for new methods of investigation and by generalizing the enormous amount of existing knowledge and experience from the study of many ore districts.

Monographic descriptions of the type ore districts play an important role in the development of the basic principles of metallogenic study.

# V. CONCLUSION

1. The Soviet scientists have created the theoretical foundation and the methods of metallogenic analysis; they have studied the special features of the metallogeny of many industrially important metals and thus to a great degree have participated in the successful discovery and recognition of the country's mineral resources. Further development of these investigations must lie in the study of the metallogeny of ore districts. The foundations of these more detailed investigations have been laid by Soviet scientists and numerous industrial geologists.

2. The metallogenic study of ore districts, on the basis of more detailed metallogenic methods than regional analysis, permits a more flexible and deeper consideration of the specific features of different ore districts and a discovery of the laws governing the distribution of the ore minerals in them, so as to increase the effectiveness of the detailed state geologic surveys and later prospecting work.

3. In addition to its practical application, the metallogeny of ore districts may yield extremely valuable material for the further clarification of a number of questions in the theory of ore formation and metallogeny:

a) the connection between mineralization and igneous activity, the migration and deposition of the ore material, and the role of the host rocks in the zonality of the mineralization;

b) the distinguishing of type ore districts as a further and deeper study of regional metallogenic units (structural and metallogenic zones and Yu. A. Bilibin's principles of the general development of mobile belts and platforms);

c) the development (in accordance with S.S. Smirnov's ideas) of a genetic classification of deposits on a geotectonic basis.

4. A detailed metallogenic study of ore districts in the interests of the further expansion and strengthening of the mineral and fuel resources of the U.S.S.R. It is a matter involving the honor of Soviet geologic science for geologists to devote all their experience and knowledge to creating new methods of investigation and new achievements in theory.

# REFERENCES

1. Abdullayev, Kh. M., GENETICHESKAYA SVYAZ' ORUDENENIYA S GRANITOIDNYMI INTRUZIYAMI [THE GENETIC CONNECTION BETWEEN MINERALIZATION AND GRANITOID INTRUSIONS]: Gosgeoltekhizdat, 1954.
2. \_\_\_\_\_, DAYKI I ORUDENENIYE [DIKES AND MINERALIZATION]: Gosgeoltekhizdat, 1957.
3. Afanas'yev, G.D., PROBLEMA GRANITOIDOV I NEKOTORYYE VOPROSY SVYAZANNOY S NIMI METALLOGENII. V KN. MAGMATIZM I SVYAZ' S NIM POLEZNYKH ISKOPAYEMYKH. [THE PROBLEM OF GRANITOIDS AND CERTAIN PROBLEMS OF METALLOGENESIS ASSOCIATED WITH THEM. IN THE VOLUME "IGNEOUS ACTIVITY AND THE ORE MINERALS ASSOCIATED WITH IT"]: Akademiya Nauk SSSR, 1955.
4. Betekhtin, A.G., O GENETICHESKOY SVYAZI GIDROTHERMAL'NYKH OBRAZOVANIY S INTRUZIVAMI. V KN. OSNOVNYYE PROBLEMY V UCHENII O MAGMATOGENNYKH RUDNYKH MESTOROZHDENIYAKH [THE GENETIC CONNECTION BETWEEN HYDROTHERMAL FORMATIONS AND INTRUSIVES. IN THE VOLUME "BASIC PROBLEMS IN THE STUDY OF ORE DEPOSITS OF IGNEOUS ORIGIN"]: Akademiya Nauk SSSR, 1953.
5. Bilibin, Yu. A., OBSHCHIYE PRINTSIPY METALLOGENICHESKIKH ISSLEDOVANIY [GENERAL PRINCIPLES IN THE INVESTIGATION OF METALLOGENESIS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 5, 1947.
6. \_\_\_\_\_, METALLOGENICHESKIYE PROVINTSI I METALLOGENICHESKIYE EPOKH [METALLOGENETIC PROVINCES AND PERIODS]: Gosgeoltekhizdat, 1955.
7. Borodayevskaya, M.B., NEKOTORYYE VOPROSY GEOLOGII, PETROGENEZISA I METALLOGENII MALYKH INTRUZIY POZDNIKH ETAPOV RAZVITIYA TEKTONOMAGMATICHESKOGO TSIKLA. V KN. MAGMATIZM I SVYAZ' S NIM POLEZNYKH ISKOPAYEMYKH [SOME PROBLEMS OF GEOLOGY, PETROGENESIS AND METALLOGENESIS IN THE SMALL INTRUSIONS OF THE LATER STAGES OF THE TECTONIC AND MAGMATIC CYCLE. IN THE VOLUME "IGNEOUS ACTIVITY AND THE ORE MINERALS

ASSOCIATED WITH IT"): Akademiya Nauk SSSR, 1955.

8. Vol'fson, F.I., PROBLEMY IZUCHENIYA GIDROTHERMAL'NYKH MESTOROZH-DENIY [PROBLEMS IN THE STUDY OF HYDROTHERMAL DEPOSITS]: Akademiya Nauk SSSR, 1952.
9. \_\_\_\_\_, STRUKTURY ENDOGEN-NYKH RUDNYKH MESTOROZH-DENIY. V KN. OSNOVNYYE PROBLEMY V UCHENII O MAGMATOGENNYKH RUD-NYKH MESTOROZH-DENIYAKH [THE STRUCTURES OF ENDOGENETIC ORE DEPOSITS. IN THE VOLUME "BASIC PROBLEMS IN THE STUDY OF ORE DEPOSITS OF IGNEOUS ORIGIN"]]: Akademiya Nauk SSSR, 1953.
10. \_\_\_\_\_, NEKOTORYYE ZAKONO-MERNOSTI RAZMESHCHENIYA ENDO-GENNYKH MESTOROZH-DENIY RAZ-LICHNYKH GENETICHESKIKH TIPOV [CERTAIN LAWS GOVERNING THE DISTRIBUTION OF VARIOUS GENETIC TYPES OF ENDOGENETIC ORE DEPOSITS]: Tr. Instituta Geol. Nauk, Akademiya Nauk SSSR, Vyp. 162, 1955.
11. Ginzburg, I.I., OPYT RAZRABOTKI TEORETICHESKIKH OSNOV GEOKHI-MICHESKIKH METODOV POISKOV [AN ATTEMPT TO DEVELOP A THEORETICAL BASIS FOR THE METHODS OF GEOCHEMICAL PROS-PECTING]: Gosgeoltekhizdat, 1957.
12. Zakharov, Ye. Ye., K VOPROSU KLAS-SIFIKATSII MESTOROZH-DENIY POLEZ-NYKH ISKOPAYEMYKH [ON THE PROBLEM OF CLASSIFYING ORE-MINERAL DEPOSITS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 5, 1953.
13. Koptev-Dvornikov, V.S., PROBLEMA MAGMATICHESKOY PETROGRAFIY V SVYAZI S FORMIROVANIYEM GIDRO-THERMAL'NYKH MESTOROZH-DENIY. V KN. MAGMATIZM I SVYAZ' C NIM POLEZNYKH ISKOPAYEMYKH [THE PROBLEM OF THE PETRO-GRAPHY OF IGNEOUS ROCKS IN CONNECTION WITH THE FORMATION OF HYDROTHERMAL DEPOSITS. IN THE VOLUME "IGNEOUS ACTIVITY AND THE ORE MINERALS ASSO-CIATED WITH IT"]]: Akademiya Nauk SSSR, 1955.
14. Korzhinskiy, D.S., OCHERK METASO-MATICHESKIKH PROTSESSOV. V KN. OSNOVNYYE PROBLEMY V UCHENII O MAGMATOGENNYKH RUDNYKH MESTOROZH-DENIYAKH [AN OUTLINE OF METASOMATIC PROCESSES. IN THE VOLUME "BASIC PROBLEMS IN THE STUDY OF ORE DEPOSITS OF IGNEOUS ORIGIN"]]: Akademiya Nauk SSSR, 1953.
15. Kreyter, V.M., STRUKTURY RUDNYKH POLEY I MESTOROZH-DENIY [THE STRUCTURES OF ORE FIELDS AND DEPOSITS]: Geogeoltekhizdat, 1956.
16. Magak'yan, I.G., GLAVNYYE PROMY-SHLENNYYE SEMEYSTVA I TIPY RUD [THE MAIN FAMILIES AND TYPES OF INDUSTRIAL ORES]: Zap. Vses. Mineralog. Obshchestva, ch. 79, no. 4, 1950.
17. Matveyenko, V.T., KRATKIY METALLO-GENICHESKIY OCHERK SEVERO-VOSTOKA SSSR [A BRIEF OUTLINE OF METALLOGENESIS IN THE NORTH-EASTERN PART OF THE U.S.S.R.]: Tr. VNII-1 Ministerstva Tsuet. Met. SSSR, Razd. II, Geol., Vyp. 9, Magadan, 1955.
18. Obruchev, V.A., METALLOGENETI-CHESKIYE EPOKHI I OBLASTI SIBIRI [THE METALLOGENETIC REGIONS AND PERIODS OF SIBERIA]: Tr. Instituta Prikl. Mineralogii i Metal-lurgii, Vyp. 21, 1926.
19. Tatarinov, P.M., V.G. Grushevoy and G.S. Labazin, Editors, OBSHCHIYE PRINTSIPIY REGIONAL'NOGO METAL-LOGENICHESKOGO ANALIZA I METO-DIKA SOSTAVLENIYA METALLO-GENICHESKIKH KART DLYA SKLAD-CHATYKH OBLASTEY [THE GENERAL PRINCIPLES OF REGIONAL METALLO-GENETIC ANALYSIS AND THE METH-ODS OF DRAWING METALLOGENE-TIC MAPS OF FOLDED REGIONS]: Vses. N.-I. Geol. Instituta, Nov. Ser., Vyp. 22, Gosgeoltekhizdat, 1957.
20. Radkevich, Ye. A., SOVESHCHANIYE O TIPAKH METALLOGENICHESKIKH KART [CONFERENCE ON THE TYPES OF METALLOGENETIC MAPS]: Iz-vestiya, Akademiya Nauk SSSR, Ser. Geol., no. 5, 1957.
21. Rub, M.G., O PETROKHIMICHESKIKH KRITERIYAKH SVYAZI ORUDENENIYA S INTRUZIYAMI [PETRO CHEMICAL CRITERIA FOR DETERMINING THE ORE FORMATIONS ASSOCIATED WITH INTRUSIONS]: Izvestiya, Akad-emiya Nauk SSSR, Ser. Geol., no. 4, 1956.
22. Satpayev, K.I., O METODOLOGII,

- FAKTICHESKOY BAZE I OSNOVNYKH VYVODAKH METALLOGENICHESKIKH PROGNOZNYKH KART TSENTRAL'NOGO KAZAKHSTANA [THE METHODS AND FACTUAL BASIS AND THE MAIN CONCLUSIONS DRAWN FROM MAPS FOR THE PREDICTION OF METALLOGENETIC OCCURRENCES IN CENTRAL KAZAKHSTAN]: Izvestiya, Akademiya Nauk KazSSR, Ser. Geol., no. 20, 1955.
23. Smirnov, S.S. and V.A. Tsaregradskiy, SEVERO-VOSTOK AZII, YEGO METALLOGENIYA I OLOVONOSNOST' [THE METALLOGENETIC AND TIN-BEARING AREAS OF NORTHEASTERN ASIA]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 5, 1937.
  24. Smirnov, S.S., OCHERK METALLOGENII VOSTOCHNOGO ZABAYKAL'YA [A BRIEF DESCRIPTION OF METALLOGENESIS IN THE EASTERN TRANS-BAIKAL AREA]: Gosgeolizdat, 1944.
  25. ———, O TIKHOOKEANSOM RUDNOM POYASE [THE PACIFIC OCEAN ORE BELT]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 2, 1946.
  26. Favorskaya, M.A., O SVYAZI OLOVYAN-
  - NOGO ORUDENENIYA S MAGMATISMOM [THE CONNECTION BETWEEN TIN ORE FORMATION AND IGNEOUS ACTIVITY]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., no. 4, 1955.
  27. Fersman, A. Ye., PERSPEKTIVY RASPROSTRANENIYA POLENYKH ISKOPAYEMYKH NA TERRITORII SOYUZA [PROSPECTS FOR THE DISCOVERY OF NEW ORE MINERALS DISTRIBUTED OVER THE TERRITORY OF THE SOVIET UNION]: Akademiya Nauk SSSR 1932.
  28. Shipulin, F.K., K VOPROSU O SVYAZI POSTMAGMATICHESKOGO ORUDENENIYA S INTRUZIYAMI. V KN. VOPR. GEOL. AZII [THE PROBLEM OF THE CONNECTION BETWEEN IGNEOUS ACTIVITY AND POSTMAGMATIC MINERALIZATION. IN "PROBLEMS OF ASIAN GEOLOGY"]: t. 2, Akademiya Nauk SSSR, 1955.
- Institute for the Study of the Geology, Petrography, Mineralogy and Geochemistry of Ore Deposits of the U.S.S.R. Academy of Sciences, Moscow
- Received November 6, 1957

# THE FOLDED BASEMENT OF THE URALS PART OF THE WESTERN SIBERIAN SHIELD

by

V. N. Sobolevskaya

## I

In studying the types of tectonic structures in the Meso- and Cenozoic deposits of the Trans-Ural area and explaining the problems of their genesis and their distribution in space, it became necessary, quite naturally, to give some consideration to the structure of the folded basement of this region and to the interrelationships between the structures of the sedimentary mantle of the platform and those of the Paleozoic basement. In this connection it also became necessary to construct a map of the hypsometric surface of the Paleozoic deposits, as it is conjectured to be in this article.

It is well known that the territory of the Western Siberian plate, which is a long-subsiding part of the young Paleozoic Ural-Siberian platform covered by a flat mantle of Meso- and Cenozoic deposits whose thickness increases toward the east and northeast to about 1,500 m in the vicinity of Tyumen', contains dislocated and metamorphosed Paleozoic strata which compose the basement complex. This Paleozoic basement, however, up to the present time has received far from adequate study, so that there are still no clear conceptions of its composition and internal structure. In spite of the considerable amount of geologic and geophysical work done in recent years, the thick blanket of Meso- and Cenozoic deposits, the limited number of deep drill-holes that reach down to the Paleozoic and their uneven distribution over the area in question and the not always correct interpretation of the geophysical data present only fragmentary information on the structure of the basement and make it impossible to form a definitive idea of the folded structures that compose it. The existing factual material give only a sketchy basis for judging that both the rocks and the structures of the basement differ little from the rocks and structures of the exposed part of the Urals, within a broad belt from the Paleozoic deposits of the Urals that are exposed in the west at least to the Tyumen' meridian in the east.

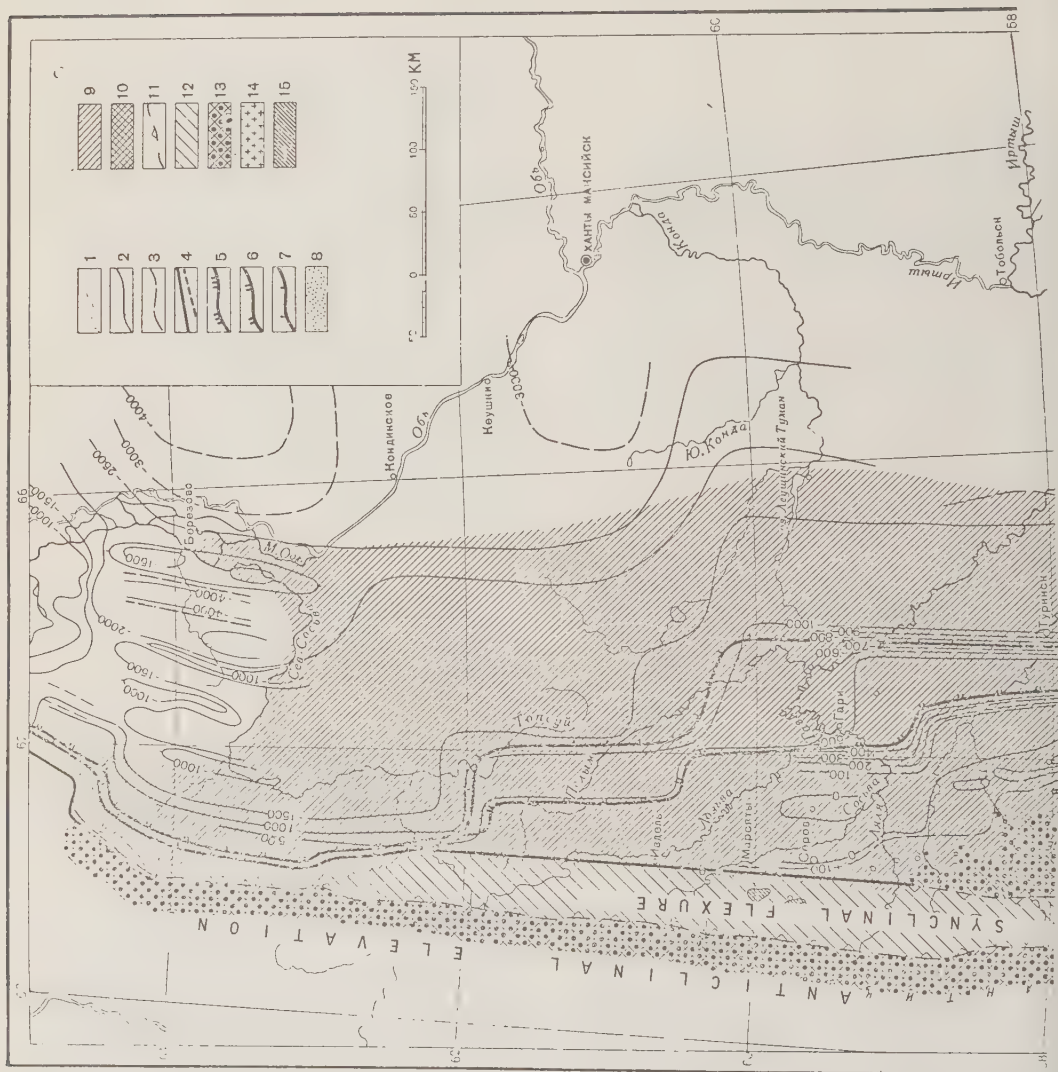
Geophysical work has established the

presence in this zone of positive and negative magnetic and gravitational fields, which suggest the existence of linear structures whose trend is evidently the same as that of the exposed part of the Urals, alternating with meridional ledges of crystalline rocks. Examples may be seen in sections drawn along the parallels of latitude through the deposits of the sedimentary mantle in the Serov and Kamyshlov areas. In the first of these, the Paleozoic deposits form a north-south anticlinal zone composed of volcanogenic and ordinary sedimentary rocks, ranging in age from Ludlovian to Givetian inclusive, and containing a large ultrabasic intrusive elongated in the north-south direction which has been traced northward for about 90 km from Vagranskaya.

On the Kamyshlov parallel, drill-holes have exposed a granitic massif that can also be traced from north to south for a considerable distance (Figs. 1 and 2).

As far as ages are concerned, the folded basement of the eastern slope of the Urals includes deposits from the Precambrian (?) (strongly metamorphosed granite gneisses at Berezovo) or Early Cambrian (?) to the Carboniferous inclusive.

Deposits such as those conditionally attributed to the Late Permian or Early Triassic and unconformably overlying the older formations, which in the Transural area usually fill the grabens, have been found nowhere within the Urals themselves. Thus the tectonic interrelationships between the Permian and Triassic deposits and the folded Paleozoic rocks that compose the basement complex may not be considered as clarified outside the areas of the grabens. Depending on how these relationships are regarded, however, the basement will be called "pre-jurassic" in some cases and "Paleozoic" in others. Formations of possible Permian-Triassic age have been discovered only along the eastern edge of the territory under investigation, by drill holes at Tyumen' and Yarsk and others around Tobol'sk. In the



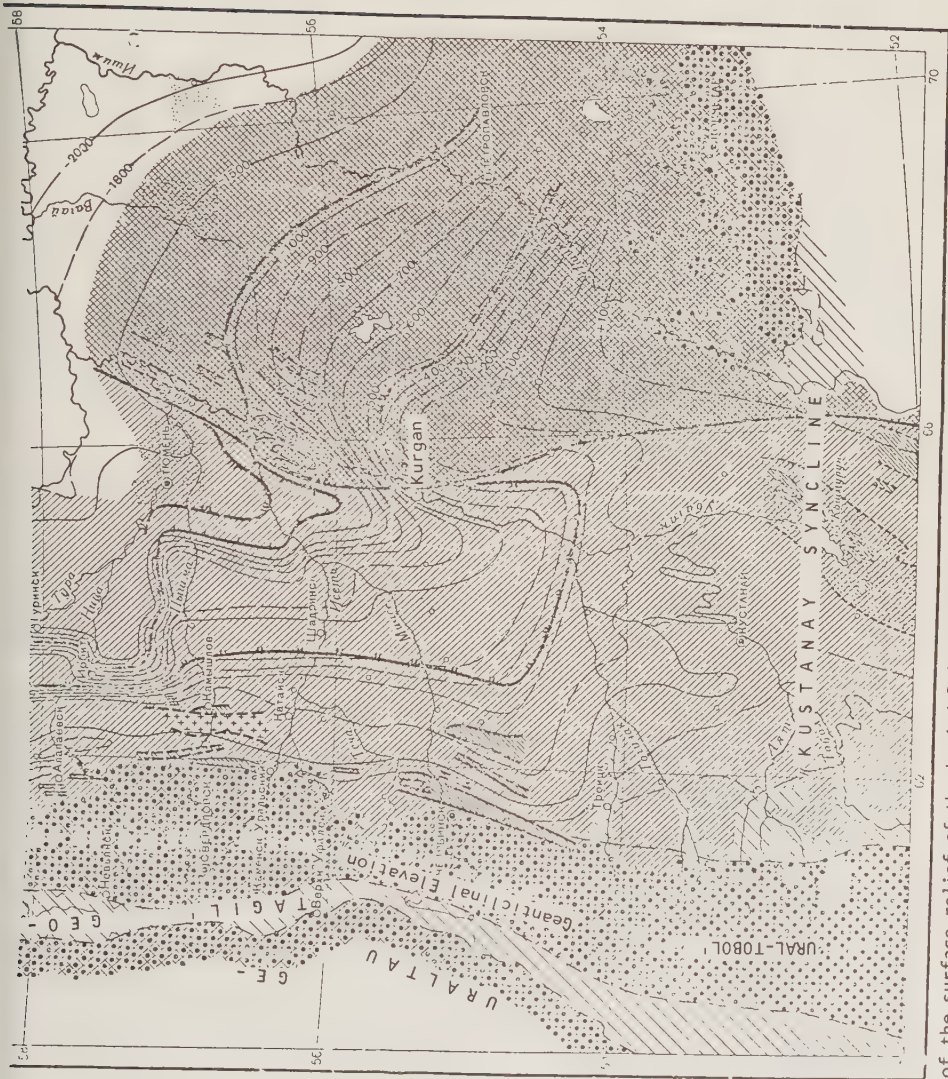


Fig. 1. Diagrammatic map of the surface relief of the buried Paleozoic deposits in the eastern slope of the Central Urals (compiled by V.N. Sobolevskaya with data from the Ministry of Geology and Conservation of Mineral Resources of the U.S.S.R., the Ministry of Oil Industry of the U.S.S.R., the Academy of Sciences of the U.S.S.R. and personal observations made in 1955):

1 -- boundaries of the Mesozoic and Cenozoic deposits; 2 -- structure contours showing the surface of the Paleozoic, based on 500 m; 3 -- supplementary structure contours; 4 -- faults, known and conjectured; 5 -- western boundary of the Permian and Triassic deposits; 6 -- western boundary of the Upper Jurassic marine deposits; 8 -- Permian and Triassic deposits; 9 -- Hercynian folded structures buried by a Mesozoic mantle; 10 -- Caledonian or Early Hercynian folded structures buried by a Mesozoic mantle; 11 -- boundaries between the main structural zones of the Urals; 12 -- geosynclinal zones; 13 -- geanticlinal zones; 14 -- the Kamyshev granitic massif; 15 -- grabens filled with deposits of various ages from the Rhaetian and Liassic to the Early Paleogene.

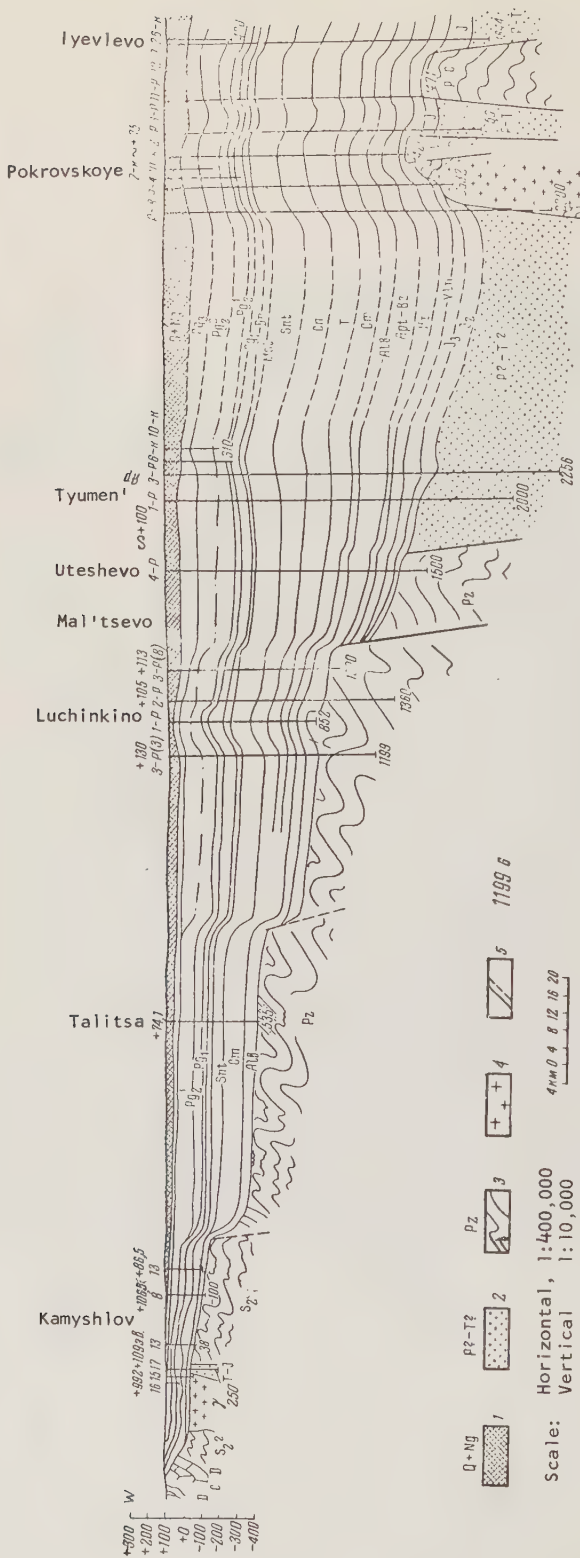


Fig. 2. Geologic section along the Kamyshlov-Tyumen'-Pokrovskoye line.

1 -- Quaternary and continental Neogene deposits; 2 -- extrusive-sedimentary rocks with gabbro-diabase dikes; 3 -- folded sediments of the Paleozoic basement; 4 -- granites; 5 -- faults, known and conjectured; 6 -- depths of drill-holes (in meters).

first two, according to A.V. Khabakov [10], the Permian-Triassic rocks may be said to include volcanogenic and weakly metamorphosed sedimentary rocks, made up of an alternation of carbonaceous clay shales, sandstones, tuffites with basic lava flows (diabase porphyrites) and olivine gabbro-diabases. This complex has here been penetrated to a thickness of more than 800 m (farther east, in the Pritobol'sk area grabens, the thickness is still greater). The age of these deposits has been established by their stratigraphic position and on the basis of phylloids, spores and single foraminifers, whose general appearance suggests that they lived no earlier than the Late Permian and no later than the Early Triassic.

The dislocations in the supposed Permian-Triassic rocks are much weaker than those of the underlying Paleozoic rocks whose occurrence may be observed in the Urals. The dip angles as measured from cores are usually  $15^{\circ}$  to  $20^{\circ}$ . Deposits of similar composition and probably of the same age have been discovered farther south, within the Kushmurun depression.

Younger in age and also considerably dislocated are the red- and gray-colored proluvial and alluvial coal-bearing series which fill a number of grabens in the Priural area; among these, the largest and best studied is the Chelyabinsk graben. These deposits correspond in time to the Rhaetian-Liassic stages.

Both the Permian-Triassic and the Rhaetian-Liassic formations are separated by angular and stratigraphic unconformities from the overlying gently sloping (almost horizontal) younger sediments of the Meso- and Cenozoic. Because of this, a number of authors have included the Permian-Triassic and the Rhaetian-Liassic in the basement complex. The possibility is not excluded, however, that in the central part of the lowland, in the more deeply subsided areas, deposits corresponding to the Permian-Triassic and Rhaetian-Liassic in age may be undisturbed and will grade gradually into the overlying strata of the Meso- and Cenozoic mantle, forming a single upper structural level with them.

Holes drilled at the western edge of the Western Siberian Lowland, in the vicinity of Ust'-Port (the mouth of the Yenisey River), which have revealed similar deposits, also supposedly belonging to the Permian-Triassic, have shown that here the latter lie with a sharp angular unconformity above Paleozoic limestones which are evidently Silurian in age. Within the Kushmurun trough they lie above the younger Paleozoic rocks. A.G. Ber's data indicate that they might belong to a synclinal structure in the Paleozoic base-

ment, but the facts supporting such a synthesis have still not been found. Most likely this is a superimposed structure; in either case, here too there is no doubt of the angular unconformity between the Permian-Triassic and the Paleozoic.

On the basis of the dislocations in the above-described formations that fill the grabens and troughs, a number of authors, as mentioned earlier, include them in the lower structural level (N.N. Rostovtsev and others), thus taking the age of the basement as a whole to be "pre-Jurassic" and attributing the origin of the dislocations in the Permian-Triassic deposits which fill the grabens to the appearance of an "Early Cimmerian phase of folding."

There exists a third point of view (A.L. Yanshin and others), moreover, according to which the dislocated sediments which occur in the grabens must be considered as a lower structural level of the sedimentary mantle; in addition, it is believed that this two-stage structure of the mantle is a feature peculiar to younger epi-Paleozoic platforms.

The dislocations in the sediments within the grabens, however, are a subsidiary and strictly local phenomenon which might have been caused by the displacement of the fault blocks along the faults that circumscribe the grabens, and may therefore not only not be used to decide the age of the basement complex as a whole but also cannot provide a basis for distinguishing the subsidiary structural stages within the mantle, since there is no evidence at all for the behavior of the deposits of the same age outside the grabens and for their relationships with the covering sedimentary strata. The distinction of a new structural stage necessarily implies forces that have produced the deformation in the sediments of the same ages not only in the grabens but over considerable areas characterized by similar conditions of development in at least one stage of geologic history -- an area, for example, such as the entire Western Siberian plate. But it has been indicated above that the structures of the Permian-Triassic and Rhaetian-Liassic deposits in the central part of the plate, where they may extend over a great area, have still not been explained. It is not impossible that the Permian-Triassic deposits here lie flat and are conformable with the overlying strata of the Meso- and Cenozoic mantle, so as to form a single structural stage with them.

In addition, local observations of the dislocations within the grabens alone would indicate the necessity of distinguishing structural stages in almost unlimited number even within the eastern slope of the Urals, since if

the northern and polar parts of the Ural slope are taken into account, the dislocated sediments (in the grabens) that are unconformable with the overlying deposits turn out to be younger formations down to the Late Cretaceous and Early Paleogene inclusive; this may be observed, for instance, in the Ivdel', Marsyat and Alapayev areas.

In view of the above, and of the existence of a huge continental stratigraphic gap at the beginning of the Mesozoic, it would be more correct in the case of the Transural area to speak not of a "pre-Jurassic basement" but only of the pre-Jurassic surface of the Paleozoic basement complex. Henceforth the present author will assume the existence of two structural stages -- the lower made up of dislocated Paleozoic rocks, or the Paleozoic basement, and the upper composed of platform blanket deposits of gently sloping Mesozoic and Cenozoic rocks which may, in the east, possibly include the top layers of the Permian deposits.

The structural map, or map of the surface of the Paleozoic basement, submitted to the reader's consideration encompasses the central Transural area and, in somewhat diagrammatic form, the Northern Transural area almost as far as the Salekhard parallel of latitude.

In 1953 N.N. Rostovtsev compiled a map of the surface of the "pre-Jurassic basement" on a scale of 1:2,500,000, with structure contours at intervals of 200 m. This map showed the southern and southwestern edges of the Western Siberian basin, including part of the territory described in this article. N.N. Rostovtsev's map in general correctly reflects the increasing depth of the pre-Mesozoic basement from west to east -- that is, from the Urals to the central part of the Western Siberian lowland -- but it is too generalized and for the present purposes does not adequately represent the typical main structural features of this region.

## II

The map of the surface relief of the Paleozoic basement of the Priural part of the Western Siberian plate that accompanies this article (Fig. 1) has been drawn to a scale of 1:1,000,000 on the basis of data from drill holes, both those which have penetrated the basement complex and others from which the depth of the basement could be calculated, as well as other geologic and geophysical material. Both primary sources and generalizing works of synthesis have been used. Among these, first mention must be made of the synthesis of geophysical data by V.K.

Bugaylo and his coauthors, encompassing much of the area under consideration here and showing the presence of structural lines following both meridians and parallels of latitude. L. Ya. Provodnikov and V.A. Nikolaev's tectonic synthesis was also used. Information covering parts of the whole area considered here was derived from maps of particular parts of the Transural area by various authors: A.P. Sigov and O.V. Burdina's map for the Kustanay district, V.D. Nalivkin's map for the Berezhovo and Sverdlovsk districts, A.L. Umovaya's and N.P. Gilevaya's map for the Makhnev district, D.B. Tal'virskiy's and I.P. Karasev's map for the structures along the Tobol and Vagay Rivers, and many other works by geologists of the Urals geological administration, the Western Siberian geological administration, the All-union Geological Institute, the Scientific Research Institute for the Geology of the Arctic, the Tyumen' Oil Geology trust, the Geological Institute of the Academy of Sciences of the U.S.S.R., the All-union Institute for Oil Geology Prospecting, as well as personal observations by the present author made while working in the field along the eastern slope of the Urals.

The map is extremely diagrammatic and does not pretend to great accuracy; nevertheless it contradicts much of the factual material existing at present, and to the first approximation has been taken by the author as the basis for his further studies of the history of the structures in the Mesozoic and Cenozoic mantle.

The topography of the Paleozoic surface is shown by structure contours at intervals of 100 m. Thus the map gives only a general idea of the surface of the basement complex, since, in view of the extremely gentle dips observed here and the interval adopted for the structure contours, all the details of the structure could naturally not be shown.

The depth of the basement within the grabens, which are extensively developed in the Chelyabinsk, Tyumen', Alapayev and Pritobol'sk areas, is not shown on the map because of the smallness of the scale, since this depth often exceeds 1,500 to 2,000 meters and in many cases has not been determined by drill holes at all.

It is not hard to see from examining the map that the structure contours showing the surface relief of the Paleozoic basement of the eastern slope of the Urals and the Transural area confirm the existence of two structurally different areas, of which one, descending by steps toward the east, extends in a broad belt parallel to the Urals, while the second, in the southeastern corner of the territory in

question, forms an enormous arch-like massif which slopes downward to the north and overlies the continuation of the Kazakhstan "shield" [9].<sup>1</sup>

The first area, as indicated above, may according to the composition of its deposits and the trends of the structures in the Paleozoic basement as revealed by geophysical methods be considered as a zone of buried folding of the Ural type. This fills a broad belt from the Urals approximately to the Tyumen' meridian. The second, which contains structures with a somewhat different trend, may be assumed to have Caledonian or Early Hercynian structures of the Kazakhstan type.

On the border between these two great basic structural zones is a depression running north-south, which is partially filled with volcanogenic-sedimentary deposits of Permian-Triassic age; this may be traced by the structure contours from Tyumen' in the north to Kushmurun in the south.

The southern part of this depression, which contains the Kushmurun trough, is also filled with sediments which are similar in age and composition to those observed in the Tyumen' area. The overall picture here is thus that of a north-south zone of depression running along the western side of the Kazakhstan massif (the shield and its buried northern extension). Along the eastern border of this zone is a series of grabens, trending northeast, in the vicinity of Tobol'sk and connected to the western border of the Kazakhstan massif. Thus the depression, which will here be called the Tyumen'-Kumurun basin, is evidently located where the Hercynian structures of the Urals connect with the older structures of the Kazakhstan type.

On the south the territory under investigation is bordered by the Kustanay arch (the so-called Kustanay bank), which is a latitudinal Mesozoic refolding of the north-south folded structures of the Urals. Within this arch the Paleozoic deposits have been uplifted to about to about the +10 -10 m level. At certain particular moments of Meso- and Cenozoic history the Kustanay arch acted as a barrier which either narrowed or cut off the communication between the northern marine basins of Western Siberia and the southern seas of the Turgay basin and the

Tura lowland. Farther to the north the Paleozoic structures rapidly subsided to the absolute level of -500 m.

The present-day surface relief of the Paleozoic basement within the zone of buried Ural folding shows (Fig. 1) that it is divided into a number of relatively broad steps which slope gradually toward the east and northeast, separated from each other by a system of steep benches running north-south parallel to the Urals and parallel or sub-parallel to the lines of latitude.

The level of one step above another in different places often reaches several hundred meters; the steps are 100 to 150 m wide. The angles of inclination of their surfaces are usually no more than  $5^{\circ}$  to  $40^{\circ}$  and rarely exceed  $1^{\circ}$  to  $2^{\circ}$ . The surfaces of the steps are quite smooth, basically reflecting the regional inclination of the topographic surface in the central part of the Western Siberian lowland. The exceptions are in certain areas usually connected to the edge of the step, where there are local outcrops of the basement and associated brachyanticlinal structures in the Mesozoic mantle, as for example in the vicinity of the village of Luchinkino and elsewhere.

Changes in the magnitudes of the dip angles and individual step-like downwarping of the Paleozoic basement have repeatedly been pointed out in many papers dealing with various parts of the eastern Urals slope and the Transural area. The existence of similar steps has also been established by seismic and geologic investigations along the southern edge of the Western Siberian lowland and in the Petropavlovsk, Assanov, Tokushin, Yakovlev, Ravkin and other areas. Here the steps are from 60 to 300 m high. On the eastern slope of the Urals S.D. Rabinovich has pointed out a step between the Southern Sos'va and the Tura Rivers, south of the main Sos'va, with a drop of more than 350 m in the depth of the Paleozoic base.

There can be no doubt of the existence of two steps on the Kamyshlov parallel -- the Kamyshlov and the Tyumen' steps. Thus, for example, a drill hole to a depth of 2,250 m in the vicinity of Tyumen' has still not revealed the folded Paleozoic basement, whereas 9 km farther west another hole shows that the basement here is at a depth of 1,400 m.

Consequently, such ruptures in the basement complex, accompanied by increases in the dip angles (or fold-like flexures) in the Meso- and Cenozoic beds, decreases in the thickness and sometimes even omission of several stratigraphic horizons from the section of the sedimentary mantle, may here

<sup>1</sup>The present article will not concern itself with the problems of the terminology of the structures of young epi-Paleozoic platforms, and will meanwhile use the terms adopted in the literature for ancient, pre-Cambrian platforms.

be considered as a rather widespread phenomenon. Data obtained from drilling testify that the individual steps or blocks shown on the map are each characterized by a different degree of completeness and thickness of the Meso- and Cenozoic section; in general, these increase from one step to another as one moves eastward (Fig. 2).

The largest steps, both in extent and vertical amplitude, are those which lie in the longitudinal direction parallel to the Urals. It is interesting to note that in a number of cases these lie on the continuation of the boundaries between the main structural geanticlinal and geosynclinal zones that have been distinguished within the exposed Paleozoic deposits of the Urals. Thus, for example, on the extension of the fault that separates the greenstone geosynclinal and the Ural-Tobol'sk geanticlinal zones, there is a step that can be traced northward for about 200 km, from the latitude of the Lobva River to the village of Burmantovo. A similar step (no less than 200 km long) may be observed along the Chelyabinsk graben and farther south; this may possibly be connected with the boundary between the Ural-Tobol'sk geanticlinal and the Ayat geosynclinal zones. The neighboring Kamyshlov step in all probability lies along the continuation of the eastern boundary of the Ayat synclinal zone, indicating that there is one of the great buried faults here as well. Thus it may be assumed with a great degree of probability that certain regional steps running in the north-south direction may be associated with very deep-seated faults that separate the different structural zones in the Paleozoic Hercynian basement. Steps extending in other directions -- that is, parallel or subparallel to the lines of latitude -- are of secondary importance; these determine the various degrees of subsidence of the north-south tectonic zones along their trend, as for example the sharp downward slope toward the north of the Ural-Tobol'sk zone at the latitude of the Tura River and of the Ayat zone at the Tcha River, etc.

It must be mentioned in passing that the large latitudinal steps located between the Pyshma and the Tura Rivers (Fig. 1) are shown by V.K. Bugailo's material, on the basis of geophysical data, as circumscribing such structures. It may be assumed that the continuation of these steps is not a matter of chance, and apparently follows the line of latitude along which a number of major structural zones of the Urals (the Alapayev-Sinar and the Ural-Tobol'sk) begin to be submerged beneath the Mesozoic mantle.

The development of such a system of longitudinal and latitudinal steps, which doubtless took place over quite a long period

of time, caused the formation of the flexure observed in the Meso- and Cenozoic beds and also controlled the different thicknesses and the completeness of the stratigraphic sections of the mantle deposits all the way down to the Paleozoic.

In addition to the step-faults that complicate the Paleozoic basement in the zone of development of buried folds of the Ural type, mention must be made of the existence of a large number of structures called grabens, which are very widespread and extremely characteristic of this area. These have been encountered almost directly next to the outcrops of the Paleozoic, stretched out parallel to the trend of the Ural folding. The grabens vary greatly in size; they are filled, as mentioned above, by dislocated deposits of various ages beginning with the Rhaetian-Liassic in the Chelyabinsk district in the south and ending with the Early Paleogene in the Marsyat and Ivdel' districts in the north.

The grabens on the eastern slope of the Urals, as may be seen from the map, do not follow any one tectonic line but are rather associated with the parallel block-faults along which the different parts (steps of the eastern slope of the Urals sank downward at various times; this is confirmed by the fact that the grabens are filled with formations of various ages.

Thus, the grabens of the Chelyabinsk zone of faults are filled with Rhaetian-Liassic deposits, whereas the Marsyat grabens, which are filled with Upper Cretaceous and Paleogene deposits, follow the line of faults farther west, along which the downward movement took place at a later time in geologic history.

The second belt of grabens is shown on the map in the so-called Tobol'sk tectonic zone that runs from Tobol'sk along the Tobol River upstream to Yalutorovsk and farther south. This zone is associated with the western branch of the Kazakhstan antecline. Here, according to information from I.P. Karasev, D.B. Tal'virskiy and others, the Mesozoic blanket contains brachyanticlinal structures connected with arches that trend northeast. Drilling and seismic work have established the existence of a number of ridges and valleys in the basement surface in this area; on the ridges the Paleozoic is directly overlain by marine deposits of the Meso- and Cenozoic mantle, of various ages from the Jurassic to the Aptian inclusive, while the hollows between the ridges contain a complex of volcanogenic-sedimentary formations of probable Permian-Triassic age which are extremely thick and apparently no different from the complex of varicolored deposits in the lower part of the section uncovered by the Tyumen' drill holes and at

Kushmurun. According to geophysical data, the thickness of this complex and, consequently, the depth of the hollow is more than 2,500 to 3,000 m. In many places holes drilled deeper than 2,500 m failed to reach the Paleozoic rocks.

On the buried ridges the surface of the Paleozoic lies at depths of about 900 to 1,000 m. These great fluctuations in the hypsometric level of the Paleozoic basement (as much as 1,500 or more meters in places no more than 5 km distant from each other) force one to believe that the arches and troughs in the Meso- and Cenozoic mantle correspond in the basement not to a system of arches and troughs, as is sometimes thought, but to a number of grabens filled with Permian-Triassic deposits and separated by horsts of the Paleozoic basement.

Sudden downward plunges, suggesting the existence of grabens in the Paleozoic basement in this area, have been encountered on the eastern flanks of the Zavodoukov, the Komissarov and many other structures, where within distances of about 2 to 3 km the level of the basement complex drops from 900 to more than 2,500 m.

The Tobol'sk zone of grabens can apparently be traced still farther south, along the western edge of the Kazakhstan massif, as far as the latitude of the Kustanay arch, where, in addition to the Kushmurun depression filled with Permian-Triassic deposits, a large number of grabens has been found east and northeast of the latter, filled to a thickness of more than 1,000 m with younger, carboniferous strata of the Middle and Lower Jurassic.

The grabens in this zone, which are evidently connected with faults, are terminated in the west by the Kazakhstan massif. The first group of grabens, in the area of the Hercynian structures of the Urals, follows an almost longitudinal trend parallel to the Urals. The grabens of the second group have an essentially different trend, since all the structural lines here run northeast, evidently reflecting the characteristic trend of the Kazakhstan folded structures.

All that has been said above suggests that the connection between the Hercynian structures of the Urals and the more ancient structures must be sought here, within the Tyumen'-Kushmurun depression.

It may be noted in passing that the gradual downward slope of the Kazakhstan massif toward the north can be seen not only from the structure contours as shown on the map, but also from direct geological observations. Drilling in the Pritobol'sk zone, for instance,

has shown that as one moves northward the raised blocks of the basement complex ("arches") are covered directly by Mesozoic deposits of increasing ages.

### III

In summing up all that has been said above, the following basic features may be noted in the structure of the Paleozoic basement of the territory under investigation up to the beginning of the Mesozoic stage of its development.

The greater part of this territory evidently contains Hercynian structures of the Ural type; only the southeastern corner is made up of the Caledonian or Early Hercynian Kazakhstan massif with its buried northern extension.

The highly metamorphosed granite gneisses discovered by drill holes in the vicinity of the village of Berezhovo are not sufficient basis for distinguishing a separate area here with a Precambrian basement, as some authors assume. These granite gneisses are more probably the nuclei of Hercynian anticlinal folded structures.

The geosynclinal development of the territory under consideration ended at the close of the Paleozoic. The beginning of the platform stage of its history was characterized by long-lasting continental conditions, from the end of the Permian through the first half of the Paleozoic to the Middle Jurassic inclusive.

At this time, the Paleozoic rocks were broken by a system of longitudinal and latitudinal faults accompanied by the formation of grabens and the filling of the latter by continental deposits of the Upper Permian and Lower Mesozoic.

Ultimately, as a result of the subsidence of the central part of the Western Siberian plate, there was a gradual involvement in the subsidence of the individual blocks that had been broken off by faults, thus causing a gradual westward transgression of the sea.

The times at which the individual blocks were drawn into the subsidence, and the corresponding pieces of dry land were covered by the marine transgression, may be determined by studying the lateral boundaries of the deposits of various Meso- and Cenozoic horizons.

Throughout the whole Meso- and Cenozoic history of the territory investigated, the northern continuation of the Kazakhstan massif

(the Kazakhstan anteklise) remained relatively uplifted, forming an extremely stable and long-developing positive structure.

Thus the factual material available at the present time suggests that the Paleozoic folded structures were not part of the surface relief of the Paleozoic basement of the Priural part of the Western Siberian plate. This applies to both the subsidiary anticlinal and synclinal structures and to the great anticlines such as those of the geotectonic zones of the Urals.

In the formation of the surface relief of the Paleozoic basement, one important factor was undoubtedly the presence of a system of faults whose main directions were oriented along the trend of the Paleozoic folding. Different portions were involved in movements in either direction along these faults, however, regardless of their internal anticlinal or synclinal structures, so that there is no basis for thinking that these structures in the lower structural stage (the basement) could have been developed subsequently (by succession) in the mantle of the platform.

Such a view of necessity involves the practical conclusion that the uplifted part of the basement disclosed by a study of the structures in the loose covering deposits is not necessarily an anticlinal structure with favorable prospects for gas and oil.

In conclusion, it would be desirable to touch on still one more question -- the structure of the young Paleozoic platforms.

Certain investigators, who divide the sedimentary mantle into two structural stages (without sufficient basis in fact, in the present author's opinion), find in this two-stage structure one of the chief distinctions between young epi-Paleozoic platforms and older ones, since in their view the sedimentary mantle covering the Precambrian platforms has only one structural stage.

In the Western Siberian plate at the present time there is no known part in which such a two stage structure of the mantle extends over any considerable area. If, however, dislocated Permian-Triassic strata are found anywhere within the limits of a major structural element of the earth's crust (a plate or at least a syncline) to be covered by horizontal deposits of the Upper Mesozoic or the Cenozoic, the conclusion should probably be drawn not that the structure of the mantle has two stages, but that there is a folded basement of younger, Early Mesozoic age.

## REFERENCES

1. Arkhangel'skiy, N.I., STRATIGRAFIYA I TEKTONIKA MEZOKAYNOZOYSKIKH OTLOZHENIY VOSTOCHNOGO SKLONA URALA V SEROVSKO-IVDEL'SKOM RAYONE. SB. RABOT PO VOPR. STRATIGR., NO. 2 [THE STRATIGRAPHY AND TECTONICS OF THE MESO- AND CENOZOIC DEPOSITS OF THE EASTERN SLOPE OF THE URALS IN THE SEROV-IVDEL DISTRICT. SYMPOSIUM ON PROBLEMS OF STRATIGRAPHY, NO. 2]: Tr. Gorno-Geol. Institute Ural'sk. Fil., Akademiya Nauk SSSR, Vyp. 22, 1953.
2. Ber, A.G., OB OTKRYTII EFFUZIVNYKH POROD V MEZOZOYE TSENTRAL'NOY CHASTI TURGAYSKOY VPADINY [THE DISCOVERY OF EXTRUSIVE ROCKS IN THE MESOZOIC DEPOSITS OF THE CENTRAL PART OF THE TURGAY DEPRESSION]: Dokl., Akademiya Nauk SSSR, t. 17, no. 1, 1949.
3. Korovin, M.V., O GEOTEKTONICHESKOY PRIRODE PALEOZOYSKOGO FUNDAMENTA ZAPADNO-SIBIRSKOY RAVNINY [THE GEOTECTONICS OF THE PALEOZOIC BASEMENT OF THE WESTERN SIBERIAN PLAIN]: Vop. Geol. Azii, t. 1, 1954.
4. Papulov, G.N., and L.A. Umova, MELOVYYE I PALEOGENOVYYE OTLOZHENIYA PRAVOBEREZH'YA R. ISETI V PREDELAKH SHADRINSKOGO RAYONA. SB. RABOT PO VOPR. STRATIGR., NO. 3 [THE CRETACEOUS AND PALEOGENE DEPOSITS ON THE RIGHT BANK OF THE ISET' RIVER WITHIN THE SHADRINSK RAYON. SYMPOSIUM ON PROBLEMS OF STRATIGRAPHY, NO. 3]: Trudy Gorno-Geol. Instituta Ural'sk. Fil., Akademiya Nauk SSSR, Vyp. 24, 1956.
5. Peyve, A.V., TIPY RAZVITIYA PALEOZOYSKIKH STRUKTUR URALO-TYAN'SHAN'SKOY GEOSINKLINAL'NOY OBLASTI [THE TYPES OF DEVELOPMENT OF THE PALEOZOIC STRUCTURES IN THE URAL-TIEN SHAN GEOSYNCLINAL REGION]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol. no. 6, 1948.
6. Rabinovich, S.D. and A.I. Yeremeyeva, MELOVYYE I TRETICHNYYE OTLOZHENIYA VOSTOCHNOGO SKLONA URALS I ZAURAL'YA. SB. RABOT PO VOPR. STRATIGR., NO. 8 [THE CRETACEOUS AND TERTIARY DEPOSITS OF THE EASTERN SLOPE OF THE URALS AND IN THE TRANSURAL

- AREA. SYMPOSIUM ON PROBLEMS OF STRATIGRAPHY, NO. 8]: Trudy Gorno-Geol. Instituta Ural'sk. Fil., Akademiya Nauk SSSR, Vyp. 24, 1946.
7. Rostovtsev, N.N., GEOLOGICHESKOYE STROYENIYE I PERSPEKTIVY NEFTE-GAZONOSNOSTI YUZHNOY CHASTI ZAPADNO-SIBIRSKOY NIZMENNOSTI [THE GEOLOGIC STRUCTURE AND THE OIL- AND GAS-BEARING PROSPECTS OF THE SOUTHERN PART OF THE WESTERN SIBERIAN LOWLAND]: Trudy Vsesoyuznogo N.-i. Geologicheskogo Instituta, 1954.
  8. \_\_\_\_\_, ZAPADNO-SIBIRSKAYA NIZMENNOST'. OCHERKI PO GEOLOGII SSSR, T. 1 [THE WESTERN SIBERIAN LOWLAND. ESSAYS ON THE GEOLOGY OF THE U.S.S.R., V. 1]: Gostoptek-hizdat, 1956.
  9. Petrushevskiy, B.A., URALO-SIBIRSKAYA EPIGERTSINSKAYA PLATFORMA I TYAN'-SHAN' [THE URAL-SIBERIAN EPIHERCYNIAN PLATFORM AND TIEN SHAN]: Akademiya Nauk SSSR, 1955.
  10. Khabakov, A.V., PODZEMNYY REL'YEF I VEROYATNYYE USLOVIYA ZALEGANIYA POROD POGREBENNOGO DOYURSKOGO FUNDAMENTA ZURAL'YA [THE SUBSURFACE TOPOGRAPHY AND PROBABLE STRUCTURES OF THE ROCKS IN THE BURIED PRE-JURASSIC BASEMENT OF THE TRANS-URAL AREA]: Trudy Vses. N.-I. Geol. Instituta, 1954.
  11. Shatskiy, N.S., MEZOKAYNOZOISKAYA TEKTONIKA TSENTRAL'NOGO KAZAKHSTANA I ZAPADNO-SIBIRSKOY NIZMENNOSTI (I VOPROSU O YAVLENIIYAKH UNASLEDOVANIYA V RAZVITII PLATFORM). SB. PAMYATI AKAD. A.D. ARKHANGEL'SKOGO [THE MESO- AND CENOZOIC STRUCTURE OF CENTRAL KAZAKHSTAN AND THE WESTERN SIBERIAN LOWLAND (THE PROBLEM OF SUCCESSION IN THE DEVELOPMENT OF PLATFORMS). SYMPOSIUM IN HONOR OF ACADEMICIAN A.D. ARKHANGEL'SKIY]: Akademiya Nauk SSSR, 1951.
  12. Yanshin, A.L., METODY IZUCHENIYA POGREBENNOY SKLADCHATOY STRUKTURY NA PRIMERE VYYASNENIYA SOOTNOSHENIY URALA, TYAN'-SHANYA I MANGYSHLAKA [THE METHODS OF STUDYING A BURIED FOLDED STRUCTURE AS EXEMPLIFIED IN THE DISCOVERY OF THE RELATIONSHIPS BETWEEN THE URALS, TIEN SHAN AND MANGYSH-LAK]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol. no. 5, 1948.

Geological Institute of the  
U. S. S. R. Academy of Sciences,  
Moscow

Received January 30, 1958

# THE QUATERNARY GLACIATION IN WESTERN TUVA AND THE EASTERN PART OF THE GORNY ALTAY

by

N. A. Yefimtsev

This article presents a preliminary regional stratigraphic subdivision of the Quaternary deposits of Western Tuva and the eastern part of the Gorny Altay, with a brief account of the supporting data. Features of past glacial history are analyzed and the conditions under which the fluvio-glacial deposits form are examined.

\* \* \* \* \*

From 1953 to 1956 the present author made a study of the mantle of Quaternary deposits on the Shapshal' Ridge and its spurs, including the Prishapshal' part of the Gorny Altay, and also the ridges of Western Sayan and the Chikhacheva Ridge and the Mungun-Tayga massif in the extreme southwestern part of Tuva (Fig. 1). In addition to the extensive development of glacial formations, the subdivision of the Quaternary deposits in this territory depends to a considerable degree on the solution to the problem of the glaciations, which in the Altay-Sayan mountain region has up to this time not been agreed upon: for example, various investigators distinguish from one to four glacial stages. This circumstance is the cause of the fact that most of the attention has had to be devoted to the problem of the Quaternary glaciation, which in turn is closely associated with the problems of distinguishing the different genetic types of Quaternary deposits, especially in view of the extensive distribution of pseudo-glacial deposits in the mountain regions.

The glaciation in the Shapshal' Ridge and the ridges of Western Sayan were treated in the 1930's by P.M. Tatarinov, V.A. Kuznetsov, K.S. Filatov [28], K.I. Postoyev [21] and Z.A. Lebedeva [13]. These investigators distinguished two glaciations in this area, considering the first to be semi-continental and the second to be of the mountain type. In postwar and most recent years the Quaternary deposits of Western Tuva as a whole have been studied by L.D. Shorygina [30] and I.G. Nordega. New information has also been compiled by V. Ye. Kudryavtsev, B.F. Selvesyuk, G.I. Ivanova, G.G. Bel'skiy and others. L.D. Shorygina, mainly on the basis of data from the Western Tannu-Ola Ridge, has discerned three glaciations in Western

Tuva, one of which is Early Quaternary; I.G. Nordega and I.S. Gudilin see a single glaciation -- Middle-late Quaternary -- for the entire territory of Tuva.

The glaciation and the relief of the western slope of the Shapshal' Ridge and the adjacent parts of the Gorny Altay have been studied by many investigators [4, 10, 19, 26]. In recent years these problems have received much attention from the geologists of the All-union Aerogeologic Trust (VAGT) -- O.A. Rakovets, I.I. Belostotskiy, I.F. Pozhariskiy, V. Ye. Gendler, G.A. Schmidt, Ye. V. Devyatkin, S.R. Mayzelis, T.S. Belyayeva and others. The problem of the former glaciation of the Gorny Altay as a whole occupies a large place in Ye. N. Shchukina's investigations. The majority of the above-named investigators distinguish two glaciations in this part of the Gorny Altay, G. Grane sees three and Ye. N. Shchukina four, of which one is Early Quaternary.

The formation of the Quaternary mantle in this territory has been determined basically by the relief of the topography, whose development completely reflects the nature and the direction of the most recent tectonic movements. Two generations or stages emerge quite clearly from a subdivision of the relief of most of the territory: a poorly dissected ancient topography (residual) elevated to a height of 2,000 to 3,000 m, and a more-or-less strongly dissected erosional and erosional-glacial (Alpine) relief. The ancient topography, which has often been called a peneplane, was not that of a flat plain, but had gentle mountain features with broad valleys sometimes cut down to depths of 400 to 600 m and gently-sloping interstream divides. This weakly dissected territory contained some individual dome-shaped monadnocks

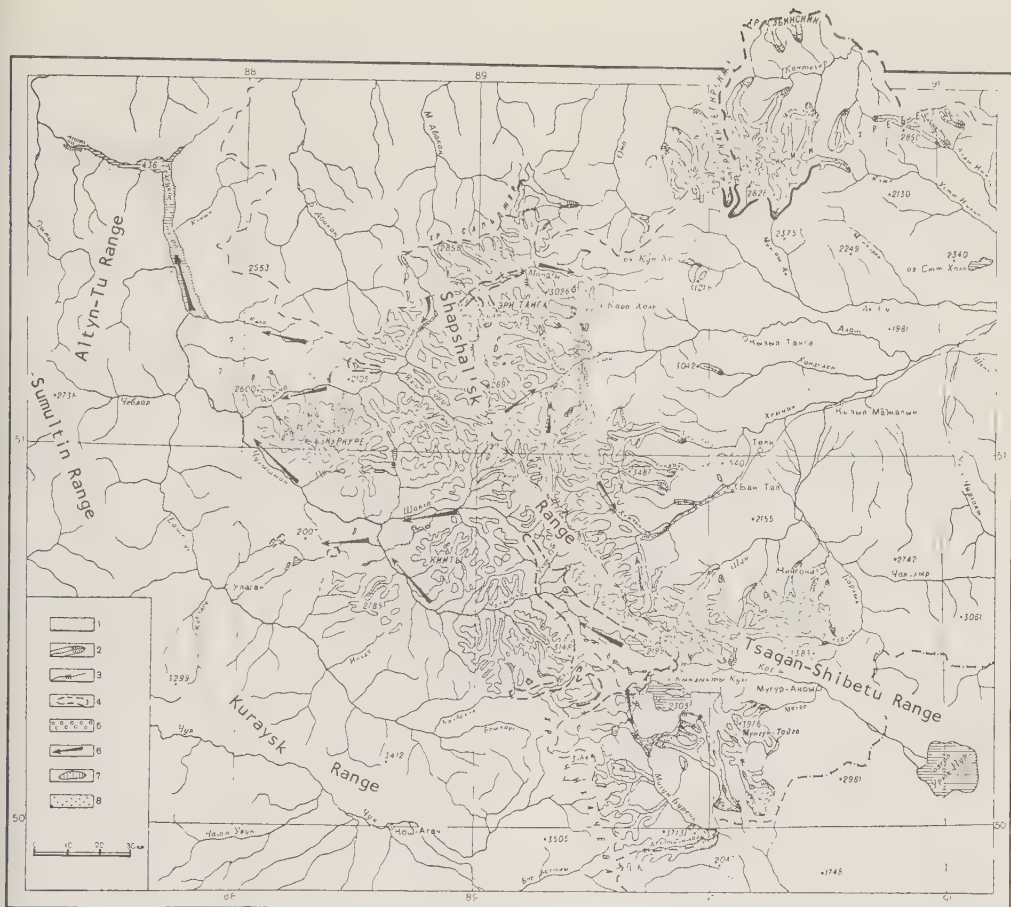


Fig. 1. Map of the last stage of glaciation in Western Tuva and the eastern part of the Gorny Altay.

1 -- glaciers; 2 -- terminal moraines; 3 -- recessional moraines; 4 -- areas of the most widespread occurrence of eskers, kames, kame terraces; 5 -- areas of the most widespread distribution of fluvio-glacial deposits; 6 -- main directions of ice movements; 7 -- present-day glaciers; 8 -- terminal moraines of the next to the last stage of glaciation.

Eri-Tayga, Kurkure, Kiyty) whose relative height was 1,000 m or more and whose diameter was from 10 to 20 km, along with low ridges usually composed of granites. Considerable areas of this residual topography have been preserved in many places in the territory under consideration, especially in the eastern part of the Gorny Altay.

The highest parts of the ridges and massifs (as much as 3,000 to 4,000 m) usually have a strongly dissected relief. Intensive exaration by glaciers has given them a typical Alpine appearance. Areas have been encountered, however, that are extensively dissected by ordinary erosion, as well as less elevated (up to 2,000 to 2,500 m) areas where there is no manifestation of glacial

activity. These are usually situated along the valleys of the largest rivers (such as the Alash).

The territory under consideration is composed primarily of Paleozoic sedimentary and sedimentary-extrusive rocks cut by granitoid intrusions. Structurally, these form a complex system of folding belonging to the Caledonian cycle. The ancient structures typically have almost no effect on the present topography. Although the prevailing trends of the structures are northeast (in Tuva) and northwest (in the Altay), the chief ridges are roughly parallel to the longitude (the Shapshal' and Chikhacheva) or the latitude (the Sayan Ridge) (Fig. 1).

The lithology of the rocks of the region had a considerable effect on the formation of the Quaternary mantle. This was facilitated by the great resistance to erosion of the granitic clastic material, despite the small area of the intrusions, so that this played a large role in the formation of the Quaternary deposits, especially glacial and alluvial. This was also facilitated by the fact that the granites are usually associated with the highest parts of the ridges, which are subjected to a greater amount of denudation.

The oldest Cenozoic deposits are the alluvial carboniferous formations (up to 40 m) in the ancient Dzhulukul' ravine<sup>1</sup> in the foothills of the Shapshal' Ridge at an elevation of 2,200 m (on the upper reaches of the Karga River). These are a group of cross-bedded gray (with dove-colored tones) polymict sands and sandy loam, containing lenses of coarse gravelly sand and sand mixed with clayey loam, and thin (0.5 m) layers of brown coal with carbonized wood remains. The sands are disrupted, dipping mainly 30° to 35° from the ridge. The bottom of this group of beds has not been exposed.

S.N. Naumova and O.V. Matveyeva have identified the following conifer pollens in the lignite and clayey loam interbeds (specimens collected by the present author in 1955): Tsuga, Abies, Picea, Pinus, Keteleeria, Torreya, Taxodium (single occurrence), and Podocarpus (single occurrence), and the following angiosperm pollens: Alnus, Betula, Carya, Pterocarya, Corylus, Salix, Tilia, and Cyperaceae (?).

S.N. Naumova and O.V. Matveyeva attribute the formation of these deposits to the Late Miocene - Early Pliocene.

Above these (possibly after an erosional interval, which could not be discovered) lie a group (up to 20 m) of yellowish-brown cross-bedded alluvial sands and sandy loam with cobbles and boulders up to 0.5 m in diameter. This alluvium bears traces of later weathering in the form of cobbles and boulders up to 0.5 m in diameter. This alluvium bears traces of later weathering in the form of cobbles and boulders that have been weathered and disintegrated to the point of becoming friable. No pollen was found in these deposits. There are similar alluvial formations in the terraces of the valleys belonging to the Ustyū-Ishkin, Alash, Ustu-Gimate, Mogun-Burun', Alty-Gimate and other rivers.

The lack of paleontological data makes it difficult to determine the age of these deposits, but such features as the considerable weathering of the material and the yellowish-brown color due to this, their occurrence on the Miocene-Pliocene carboniferous deposits and their disrupted state point to the Pliocene age of these deposits. The fact that they are preserved as fragments in the terraces of relatively deep present-day mountain valleys may, in the author's opinion, serve as a certain basis for assigning them to the late Pliocene.

On the basis of V.I. Gromov's subdivision of the Quaternary system, these supposedly Upper Pliocene alluvial deposits would be assigned to the bottom division of the system - the Eopleistocene (Table 1). This agrees generally with the views of L.D. Shorygina [30], Ye. N. Shchukina, G.F. Lungersauzen and O.A. Rakovets [14]. These investigators began much earlier to assign similar deposits of Western Tuva and the Gorny Altay to the Quaternary system -- to its Lower Pleistocene division in the subdivision of 1932.

The Eopleistocene alluvial deposits are usually found in terraces from 30 to 100 m and are primarily yellowish-brown sandy weathered gravels with boulders up to 1.5 m in diameter (in the Alash valley) or sands with a small percentage of gravels and boulders (in the Karga valley). The thickness of the deposits vary from 2 to 3 m (3 m in the Ustyū-Ishkin River terrace) to 20 m (in the Ustu-Gimate River valley). These fairly large accumulations of alluvium typically occur within relatively small areas in the remains of terrace bases. In most cases only a few cobbles and boulders are preserved on their surfaces (in the valleys of the Ustyū-Ishkin, the Alash and other rivers).

The Eopleistocene is also probably the age of the proluvial deposits that make up the lower part of the section in the large proluvial aprons and cones composed of yellowish-brown or red-brown gravelly clay and sandy loams and sometimes plastic clays (in the Khondelen and Alash River valleys). In similar deposits in the Rudnoy Altay pollen have been found that date them in the Pliocene [25]; it may be assumed that these deposits belong to the top of the Pliocene -- that is, to the Eopleistocene. The Eopleistocene is evidently also the age of the breccias of proluvial origin along the southern ridge of the Tsagan-Shibetu, on the lower reaches of the Karga River, and on the left bank of the Khemchik valley between the mouth of the Alash and the village of Aldyn-Maadar.

<sup>1</sup>The Dzhulukul' ravine is the northern part of the basin of the same name, which corresponds to the upper parts of the Chulyshman and Karga valleys.

There are no glacial formations of this age in the territory under consideration. It is true that the yellowish-brown deposits of

Table 1

A Preliminary Stratigraphic Subdivision of the Quaternary (Anthropogene) Deposits of Western Tuva and the Eastern Part of the Gorny Altay

System	Series	Stage	Deposits
Quaternary (Anthropogene)	Holo-cene		Terminal moraines of recent glaciers Proluvial cones connected with river valleys (gray sandy and clayey loam with gravel) Alluvium of low and high river valleys (gray boulder conglomerates and conglomerates with boulders)
	Pleis-tocene	Upper	Recessional moraines Moraines of the last glacial stage: terminal, lateral and ground moraines Fluvioglacial deposits of the last glacial stage -- intra-glacier (sands, boulder sands) and extra-glacier (boulder conglomerates and conglomerates with boulders) Lacustro-glacial deposits of the last glacial stage (horizontally bedded clay sandy loams and sands) Proluvial cones connected with river-valley terrace I (gray sandy and clayey loams with gravel) Alluvium of river-valley terrace I (gray boulder conglomerates and conglomerates with boulders)
		Middle	Terminal moraines of the next to the last stage of glaciation Deluvial-alluvial gravelly sandy loams with <u>Elephas primi-genius</u> of the early type Alluvium of river-valley terrace II (gray conglomerates with boulders) Proluvial cones connected with river-valley terrace III (gray sandy and clayey loams with gravel)
		Lower	Alluvium of river-valley terrace III (gray conglomerates with boulders)
	Eopleis-tocene		Proluvium (yellow-brown sandy and clayey loams with gravel, red-brown clays with rounded and angular gravel) Alluvium (weathered yellow-brown gravels with boulders)
Neo-gene			Alluvium of buried drainage system (greenish-gray carboniferous sands and sandy loam with numerous remains of wood). The pollens contain a predominance of <u>Tsuga</u> , <u>Picea</u> , <u>Carya</u> , <u>Pterocarya</u> .

the Kubadru River valley (the left tributary of the Bashkaus) in the adjacent part of the Gorny Altay have been identified by Ye. N. Shukina as the moraine of the Early Pleistocene (Bashkaus) glaciation. A study of the section of these deposits by the present author, however, has shown that it is entirely composed of well rounded boulders and cobbles, without any angular fragments; the cement contains sand and gravel, the granulometric composition of the deposits changes markedly to smaller sizes along the valley (the maximum size of the boulders, for example, decreases from 1 to 0.5 m in a distance of 11 km), the whole stratum (up to 40 m) has a distinctly layered character due to the presence of lenses of sand and fine gravel, and there is a considerable concentration of pollen

(single specimens, according to Ye. N. Shchukina). All this testifies to the alluvial origin of these deposits; the large proportion of weathered material, which is also stressed by Ye. I. Shchukina (according to her, the limestone cobbles and boulders are altered to marshallite), along with the presence of pollen of representative Late Tertiary flora, indicate that the deposits are of Eopleistocene age. In other words, it is impossible to agree with the Early Pleistocene glaciation discerned by Ye. N. Shchukina in the deposits of the Kubadru River valley.

The Pleistocene deposits differ from the Eopleistocene in the absence of weathered material, their good state of preservation and their gray color. Their interrelationships

with the deposits of the Eopleistocene show no manifestation of any stage of tectonic activity at the border between the Eopleistocene and the Pleistocene.

The Pleistocene deposits can be quite clearly divided into glacial deposits, contemporary non-glacial and pre-glacial deposits. The age of the glaciation, as determined by the fauna of the Upper Paleolithic complex, is no earlier than the middle of the Middle Pleistocene, according to V.I. Gromov's investigations [5]. There were two stages of glaciation -- the next to the latest and the latest.

The Lower Pleistocene deposits are difficult to distinguish from those of the lower half of the Middle Pleistocene, and are thus considered together with them (Table 1). The alluvial deposits of this age have a typically limited distribution, which is due to the great amount of erosion by rivers during the period of glaciation, as a result of which the pre-glacial -- super-floodplain -- terrace III and all the older ones were almost completely destroyed. The alluvial remnants of super-floodplain terrace III are usually thin beds of gravel or boulder gravel. This interval of time was characterized by relative lowering of the individual foothill areas, so that the alluvium of this age lies directly on Eopleistocene alluvium (in the valleys of the Rivers Mogun-Buren', Ustu-Gimate and others) (Fig. 2). It is frequently less coarse than the alluvium contemporaneous with the glaciation. The differing heights of the terraces of the same age in different valleys, and sometimes in the same valley, as well as

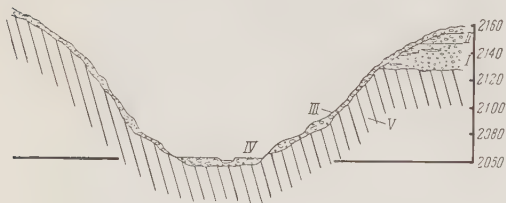


Fig. 2. Diagrammatic cross section of the Ustu-Gimate River valley.

I -- yellowish-brown alluvial conglomerates with boulders (Eopleistocene); II -- gray alluvial boulder conglomerates (bottom and lower half of the Middle Pleistocene); III -- moraine from last glaciation (Upper Pleistocene); IV -- river-valley boulder gravels (Holocene); V -- shales ( $P_2$ ).

the difference in their amounts resulting from the above-mentioned erosion by the rivers of the glacial period, make their correlation very difficult. In each specific case the age of the alluvium of the terrace must be determined independently from a whole complex

of indications.

The proluvial deposits of the Early and early Middle Pleistocene, which are sometimes of great thickness, lie on the yellowish-brown Eopleistocene alluvial and proluvial formations (on the upper reaches of the Karga River and in the Khondelen River valley). These in turn are covered in some places by the terminal moraines of the next to the last and the last stages of glaciation (in the valleys of the Tolayta, the Arta-Shigetey and the Askhatiin-Gol Rivers in the extreme southwest of Tuva); they are proluvial deposits of large- and small-grained gravel in clayey and sandy marls, whose predominantly gray and dark gray color is due to the color of the original material. The absence of glacial deposits of the Early and lower half of the Middle Pleistocene makes it impossible to suppose that there was any glaciation during this time.

The deposits of the upper half of the Middle and of the Late Pleistocene include alluvial, proluvial and all the formations of glacial and combined glacial-aqueous origin.

The alluvial deposits of this age make up the super-floodplain terraces II and I; they are composed primarily of gray boulder gravels. The sizes and compositions of the boulders in them vary according to the morphology of the valleys and the strength of the water currents in them and to a considerable degree on the rock composition (boulders of shale are very rarely encountered). Super-floodplain terrace II has been preserved only in a few individual valleys; in the Barlyk River valley, for example, along with the accumulative, most widespread super-floodplain terrace I which is 3 to 5 m high, there are considerable traces of accumulative (in some places erosional-accumulative) super-floodplain terrace II, 12 to 15 m high. This may also be traced along the left tributary of the Barlyk -- the Bol'shoy Ak-Khem River. On the left bank of the latter the level of super-floodplain terrace II corresponds to the deluvial-alluvial deposits of the Chingekat, which contain super-floodplain terrace I. In these deluvial-alluvial deposits of the mouth of the Chingekat Stream, at a depth of about 7 m, local workers in 1956 discovered a tooth identified by V.I. Gromov as that of *Elephas Primigenius* of the early type. This early mammoth, according to V.I. Gromov [6], existed from the second half of the Middle Pleistocene; thus this find approximately establishes the age of super-floodplain terrace II as the second half of the Middle Pleistocene.

Super-floodplain accumulative terrace I, whose height averages from 3 to 12 m

(considering the intermediate level between it and the floodplain as a high floodplain), with few exceptions occupies a prominent position in the river valleys. The clear connection between the terrace and the terminal moraines indicates that it is contemporaneous with the last phase of glaciation (Fig. 6). In the eastern part of Tuva, according to investigations by I.S. Gudilin and others, the terrace deposits connected with terminal moraines contain remains from the Upper Paleolithic faunal assemblage. All this serves as a basis for assigning this terrace to the Late Pleistocene.

The proluvial deposits of the upper half of the Middle and of the Late Pleistocene are in most cases quite clearly subdivided. Where the terrace dating from the time of the glaciation is enclosed by older alluvial or proluvial deposits, the river-valley proluvial cones connected with it as well as with the base are also enclosed. In these cases their area is smaller than that of the older deposits. In valleys where this terrace is not set into an older bottom, because of the tectonic peculiarities of the area (which is the case, for example, in the upper Karga valley, the lower part of the Oyuk-Khem tributary and in many places in the Khemchik River valley), the extensive proluvial aprons are superimposed. There is no essential difference in composition and structure between the proluvial deposits of this age and the older ones.

The deposits left by the ice and the streams of water associated with it will be discussed below, along with the problems involved in the glaciation.

The holocene deposits in the territory under consideration include alluvium of floodplains (low and high),<sup>1</sup> talus, especially in glacial troughs and cirques, and deposits of proluvial cones associated with floodplains. The formations of this age usually have a limited distribution.

\* \* \*

The nature, position and interrelationships of the briefly analyzed Neogene-Quaternary deposits and the morphologic peculiarities of the territory under consideration suggest a definite picture of the development of its surface relief during this time. Thus the complete absence of cobbles and boulders in the above-described carboniferous strata (Upper Miocene - Lower Pliocene), which occur at

the bottom of the southern slope of the Shapshal' Ridge in the area of the vestigial Dzhulukul' ravine, indicates that this area had a very flat relief during the time of the formation of the carboniferous deposits. The Shapshal' Ridge, which now rises steeply 1,000 to 1,500 m above the weakly dissected surface of the vestigial relief, is evidently a younger formation, since to judge by the cobbles and boulders in the mainly Eopleistocene deposits above the carboniferous ones, the ridge began to be uplifted in the Middle Pliocene or the end of the Pliocene and beginning of the Pleistocene. This fact, along with the presence in the ridge (especially in its continuation, the Tsagan-Shibetu ridge) of parts of the poorly dissected residual surface, suggests that there were movements in the Pliocene which caused an essential reordering of the topography. This was accompanied by a partial rearrangement of the drainage system, as shown by the preservation of remnants of river valleys within the ridge which do not correspond to the present drainage net (between the valleys of the Maganatta and Saylykhem Rivers, the Kozher and Tashtukhol' Rivers and others).

The Pliocene rearrangement of the topography, which took place against an overall uplift of the great Altay-Sayan mountain region, was far from affecting the entire region. This is testified by the extensive areas of morphologically homogeneous, primarily medium-elevation (2,000 to 2,200 m) erosional surface relief, especially in the Alash and Usty-Ishkin River basins. The very clear transitions between river valleys of this surface relief, on the upper reaches, and those of the residual relief, indicate a period in which the drainage system was cut into the surface. The presence of Miocene-Pliocene alluvial deposits in the residual parts of the relief (in the Dzhulukul' ravine), and of predominantly Eopleistocene deposits in the present-day relief (in the Usty-Ishkin, Alash, Mogun-Buren' and other river valleys) shows that this period of incision of the drainage net was mainly in the Pliocene and Eopleistocene and did not end with the glaciation, since on the upper reaches of the Alash River, in the Dzhulukul ravine and other places the dissection left quite large areas of residual topography which were then preserved by the glaciers.

This reordering of the topography, as a result of which parts of the preserved residual river valleys were sharply cut off and bent like elbows into new directions (the Monaga River valley with Lake Kara-Khol', the Myunik River valley and others) was evidently accompanied by faulting. This is also shown by the steep, high slopes of the Shapshal', Tsagan-Shibetu, Chighachev and other ridges, with the dislocated Tertiary

<sup>1</sup> The high floodplain may have been formed at the end of the Late Pleistocene; the data for a final solution of this problem is not available.

deposits at their foothills (on the upper reaches of the Karga) and thick accumulations of proluvium. The faults often appear to be inherited, as indicated by the clear correspondence between the sides of the ridges or the new directions of the drainage net and the lines of old faults. According to V. A. Kuznetsov [11], A. L. Dodin, G. I. Ivanova and G. G. Bel'skiy, for example, a zone of faults runs along the southern edge of the Tsagan-Shibetu and the southern part of the Shapshal' ridges. Here Jurassic gravelites and conglomerates, pressed between Devonian and Silurian deposits, are preserved in a narrow belt. Part of the Alash River valley, now occupied by Lake Kara-Khol', follows the line of a Paleozoic fault, according to V. Ye. Kudryavstev and B. F. Sel'vesyuk. The presence of a nearby residual river valley indicates that this area was formed at the time of the topographic rearrangement mentioned above. The inherited nature of the most recent tectonic fault lines is shown by the adjacent territory to the east [8].

The differential movements of the Pliocene-Eopleistocene mark one of the most important stages in the history of the topography, which owes the main features of its present appearance to this stage. These movements determined the different effects of the exogenic processes on the various parts of the territory under consideration, so that now one may observe two clearly differentiated generations in the topography -- a residual, poorly dissected relief which is chiefly Tertiary (Neogene), and a more-or-less deeply dissected erosional and erosional-glacial relief of Quaternary age. The above-mentioned movements do not exclude later ones, which differ, however, in not having brought about any noticeable reordering of the topography. The general plan of dissection of the topography at the beginning of the glaciation, for example (with the exception of areas of intensive exaration by the ice), was very close to that of the present day, and there is no basis for supposing that there was any interglacial rearrangement of the relief.

The main factor in the formation of the relief of the Altay-Sayan mountain region was tectonic movements such as anticlinal uplifts with displacements along fault lines; in individual areas these produced a rather clear block-structure. It can be shown that the latter is very unevenly developed and is typical of areas surrounded by ravines (the Khemchik and Dzholukul'), where the differential nature of the movements is more sharply expressed.

In certain areas of the Khemchik ravine the great thickness of the yellowish-brown proluvial deposits of supposed Eopleistocene age (more than 100 m around the village of

Aktavrak) is an indication of relatively active subsidence at this time. Lack of data on the total thickness of the ravine's deposits and the age of their lower horizon makes it impossible to determine the beginning of their formation; this may possibly be in the Paleogene or even the Mesozoic.

The conclusion made here regarding the relatively great age of the mountain relief of the territory under consideration agrees with the opinions of many investigators of the Altay and the Sayan [7, 17, 20, 23, 24, 32], and stands in opposition to the view that the mountain relief of this part of the territory is primarily Middle and Late Pleistocene.

\* \* \*

In taking up the problems of the Quaternary glaciation, it must be noted that its remnants and traces are extremely well preserved and clear almost everywhere. The identification of the erratic material was considerably facilitated by the fact that in the majority of cases granitic material was carried from the center of the glaciation into extensive areas of Paleozoic extrusive-sedimentary rock. The present author has studied glacial formations in more than sixty valleys of the Yenisey and Oba basins and closed depressions of the Mongolian People's Republic, throughout a quite extensive territory with a variety of morphology and climatic conditions.

Moraines -- terminal, lateral and ground-are the most widespread. Among the terminal moraines there are three quite clearly distinguished groups of different ages. The oldest of these is found only in the extreme southwestern part of Tuva. Thus the terminal moraine field of the Tolayta River valley (on the southern slope of the Mungun-Tayga massif) does not have a uniform relief. The typical hill-and-ridge relief of most of its area differs sharply from the southwestern end of the moraine field, whose relief is flat and wavy, without hills and ridges. This part is obviously older than the main part, which rises above it in a distinct step 15 to 30 m high; it could have been formed only by long-lasting leveling out of the usual terminal-moraine relief. This fact and others similar suggest that there was a certain earlier stage of glaciation (an earlier phase).

The second group of terminal moraines is the most widespread and appears to be the only one in the majority of the glacial valleys. The relief of these terminal moraines contains hills and ridges with an amplitude up to 20 m. These moraines usually occur in more-or-less extensive fields and do not have the classic shape of a bank. Depending

on the morphology of the valleys and on the sizes and motions of the glaciers, the terminal moraines of this group may have a variety of areas and thicknesses. In the broad valleys of the Kara-Khol' (the right tributary of the Kantegir) and the Chul'chya Rivers (in the Alash basin), for example, they are about 5 to 6 km long and 1 to 1.5 km wide and have a visible thickness of 30 to 40 m, whereas in the narrow valley of the Ulug-Orug River the terminal moraine, with an area of 1.5 to 2 km<sup>2</sup>, is up to 125 m thick. The most extensive terminal moraine fields were left by glaciers in the foothills of the southern and western slopes of the Mungun-Tayga massif and the Askhatin-Gol valley (Fig. 1).

The elevation of the terminal moraines of this group reveals a regular increase in their altitude from northwest to southeast, which is caused mainly by the increasing aridity of the climate in this direction. Thus, for example, the terminal moraines on the upper reaches of the Kantegir and the Alash are at the levels of 1,250 and 1,500 m, whereas those in the southwesternmost part of Tuva are from 1,800 to 2,300 m in elevation.

The absence of other terminal moraines in most of these valleys and the freshness of their shapes suggest that these moraines belong to the last glacial stage. No traces of glaciation appear below the terminal moraines of this group, so that one may conclude that the glaciers of this last phase of glaciation often moved farther than those of the initial phase.

Besides the terminal moraines of the last and penultimate phases of glaciation, one more terminal moraine may be traced in the upper reaches of certain valleys, especially in the southwesternmost Tuva and to the west of the Shapshal' Ridge. In the valleys of the Mungun-Tayga massif this moraine shows a few traces; it is made up primarily of thin (some 10 to 20 m) morainal deposits with a gently hilly relief. In the Chulyshman basin they are not essentially different from the terminal moraines of the last phase of glaciation; they form the dams containing many lakes, including such large ones as Ity-Kul' on the upper reaches of the Chul'chya and Eri-Kul' in the Suu-Katar valley. This upper terminal moraine is lacking in most of the valleys of Western Tuva; this is evidence that it is, actually, a recessional moraine. The recessional moraines were formed under such conditions of degradation of the ice of the last glacial phase that a major factor was the individual movements of the glaciers as determined by the glacier's source of supply, the slope of the glacier's channel, the exposure, the absolute elevation, etc. The combination of these factors determined the different glacial conditions which produced

either a single terminal moraine or else from one to four recessional moraines in addition to the terminal moraine of the last phase [9].

The moraines enumerated above do not differ generally from each other in the type of material composing them. They are all made up primarily of sandy loam with a certain amount of coarse material. The content of the pelitic fraction (particles < 0.01 mm) varies from 5 to 20 percent; the greatest content is found in moraines formed mainly from Paleozoic shale and sandstone strata. In most cases, however, there is a predominance of granitic material in the moraines. The coarse material consists chiefly of unrounded or poorly rounded rock fragments (the largest blocks in the moraines, which are for the most part granite, reach 5 to 7 m in diameter). Along with these, there is always rounded material in the form of cobbles and boulders, both scattered and in lenses; their presence is the result both of the work of ice-water streams and of the accumulation of preglacial valley alluvium by the glaciers. The amounts contributed by these two sources are far from equal, however; only in the terminal moraines of glaciers that have emerged into the foothills may one find a certain percentage of preglacial alluvium, whereas the glaciers that ended in narrow valleys contained ice-water streams and the rounded material in the moraines is due entirely to their activity.

The moraines in the valleys of the different basins are almost the same in color -- they are generally ash-gray throughout the area (ranging from light ash-gray to gray). The boulders in the moraines typically lack any strongly marked banding. There is no weathered material in the moraines, with the exception in a few rare cases of assimilation of Eopleistocene alluvium (in the Chulyshman valley, above the right tributary of the Srednyy Kulash). The thickness of the terminal moraines varies from 40 to 60 m in the majority of cases to 100 m or more in some moraines (in the Ulug-Orug valley).

Such typical features of the moraines as the absence or poor development of bedding, the predominance of unrounded fragmental material along with a considerable content of cobbles and boulders with fluvial type rounding, the lack of orientation in the fragmental material, and the considerable content of argillaceous matter make it possible to determine the genetic type of the moraine correctly in most cases. Only a full examination of the whole complex of indications both in the moraine itself and the glacier's period of activity in the valley, however, will guarantee complete reliability in this determination. For example, no other genetic types of

Quaternary deposits will produce such typical crest-like shapes as are formed by the erosion of moraines. The morainal relief is no less diagnostic in the majority of cases.

In all the valleys, along with the terminal moraines of the last phase of glaciation, one may with various degrees of distinctness trace lateral moraines which are basically composed of the same material as the terminal moraines. These look like crumbling terrace steps, of which the most distinct is the uppermost. This marks the greatest height of the ice and becomes lower at the glacier's snout, finally merging with the terminal moraine. In valleys with gently sloping sides the lateral moraines clearly denote the upper limit of the glacier's ice in the last glacial phase. The absence of morainal material (especially boulders) above the lateral moraines, frequently on completely flat parts (which eliminates the possibility that they may have subsequently been eroded), indicates that the glaciers of the latest phase were the greatest in size.

The lateral moraines are thickest and most distinct at the mouths of dammed-up tributaries along which glaciers did not descend. Here they are often of considerable breadth and have a typically morainal hill-and-ridge relief with small lakes (such as at the dammed-up Lake Kara-Khol' in the Kantegir basin). The position of the lateral moraines is also significant in certain other conditions. The glacial valleys of the rivers on the southern slope of the Mungun-Tayga -- Tolayta and the Atra-Shigetey massifs, after emerging from them, are cut for a short distance (to 200 to 300 m) into the relatively flat foothill area. Here the lateral moraines lie on the interstream parts of the valleys as low, gently sloping banks from 100 to 700 m wide. When the depth of the valley in the area of the cross section (Fig. 3) is only about 200 m overall, the width of the lateral moraine does not exceed 600 m. From this it is clear that the glaciers of the Mungun-Tayga massif, including those of the earlier phase, developed after the river valleys had begun to be cut. A similar conclusion is suggested by the position of the lateral moraines in the valleys with sharp bends: thus, for example, the Myunik River valley (in the Kantegir basin), in emerging from the Sayan Ridge, turns at an angle of about  $90^{\circ}$  (Fig. 1). The lateral moraine, which lies partly on the flat part of the interstream area next to the valley (on the left bank) clearly follows the bend of the valley. This position of the lateral moraines in the cases noted above can be explained only by the small depth of the valleys, which could not fully contain the ice of the glaciers as they emerged from deeper parts of the mountain. The glacial carving of the river valleys is also shown

by the fact that the terminal and lateral moraines are to be found in valleys that contain supposedly Eopleistocene alluvial deposits.

A comparison of such facts as the clear connection between super-floodplain terrace I and the terminal moraines of the last glacial phase and the existence of an older terminal moraine and of a super-floodplain terrace II,

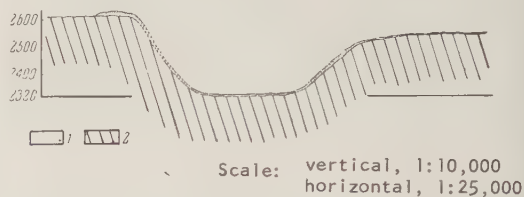


Fig. 3. Cross section of the Arta-Shigetey River valley.

1 -- moraine; 2 -- shales ( $P_2$ ).

which was dated approximately by the early mammoth found in it, compels the suggestion that the older terminal moraine and the super-floodplain terrace II are contemporaneous with each other. In this case the age of the glaciation may not be considered earlier than the middle of the Middle Pleistocene. The lack of interglacial deposits and of other indications of an interglacial period make it impossible to consider it as proven that there were two independent glaciations; therefore they are called phases. Probably the glaciation was a single one.

Fluvioglacial formations represented by eskers, kames and kame terraces are widespread in areas covered by semi-continental glaciation. The most extensive distribution is seen in broad residual valleys (in the Dzhulukul ravine, on the upper reaches of the Alash, in the Saygonysh River valley at the foot of the Abakan Ridge and in other places; Fig. 1). These formations are associated primarily with areas having the smallest inclinations of the bottom, indicating their genetic connection with "dead" ice in the concluding stage of glaciation. This is especially noticeable when such forms (for the most part eskers) are encountered in glacial troughs (in the Khemchik, Tashtukhol' and Chul'chya River valleys, in the Chulyshman basin and elsewhere) and even in Kars (in the Chundozyn River basin). Combinations and transitions from one form to another are notable; this is an indication of the common origin of these formations. In most cases the eskers, kames and kame terraces are composed of horizontally bedded or cross-bedded sands, sometimes with an admixture of gravelly and pebbly material (in the kame terraces) and individual fragments and boulders. The latter often lie on the

surfaces of these formations. In dome-shaped kames ("esker domes"; [1]) one may sometimes encounter piles of well-rounded boulder conglomerate (in the Kumyye River valley). The complete absence of any mantle of morainal matter is typical in all these formations. This circumstance, along with the location of eskers in individual cases on high points of the relief of the glaciers' beds (in the Dzulukul' ravine) and their rather steep sides, serves to confirm the supposition that the material was accumulated by water streams on the surface of the ice. The connection between the kame terraces and the bottoms of the slopes and the clear contacts with the ice on the slopes of the kame terraces indicate that they were formed primarily in thawed areas during the final stages of degradation of the glaciers [33].

The final stage of glaciation was characterized by uneven retreats of the glaciers, as determined by the differences in the way they were supplied, the shapes and inclination of the glacial channels, etc. The glaciers in tributary valleys often continued to exist even when in the main valleys the ice had been considerably degraded. Emerging into the main valleys, the tributary glaciers formed dams across the upper parts of the trunk valleys. The result was the formation of glacial lakes in which horizontally bedded clay and sand deposits accumulated. Examples of such basins are the parts of the Nemchik valley above the right-hand tributary, the Ary-Khem, where up to 50 m of sandy clay deposits were formed, and the Chulyshman River valley above the Shavla tributary, in which horizontally bedded clays were deposited to a thickness of 50 m (Fig. 4),

as described by V.P. Nekhoroshev [19] and L.I. Semikhatov [26]. These clays have a very fine composition: of 33 specimens analyzed for their grain-size composition, by Robinson's method, 18 contained more than 50 percent of particles less than 0.005 mm and 22 contained more than 70 percent of particles less than 0.01 mm in size. No regular change was noted in the grain-size composition from the top toward the bottom of the series. Two extreme examples are cited from the data on the Grain-size analysis (see Table 2).

The thickness of the clays gradually decreases upstream along the valley (from 50 m opposite the mouth of the Yelandu River to about 2 to 3 m above the mouth of the Asolak River). Horizontally bedded deposits are encountered in lenticular form within the moraines and under them (mainly outside the territory under consideration. The difference consists in the fact that these contain boulders and interbeds of morainal matter (in the Kubadru River valley), indicating that they were formed by the meltwater streams from the glacier. The horizontally bedded formations, both under and above the glaciers, contain calcareous concretions (Fig. 5), showing the similarity of the conditions in the medium in which they were formed. This similar medium consisted of closed or almost closed basins beneath the ice as well as elsewhere, during the degradation of the glaciers of the last phase. Similar horizontally bedded deposits, especially within the moraines, are sometimes also attributed to interglacial (or interphase periods and are nevertheless used for the stratigraphic subdivision of the morainal series. This, however, is contradicted

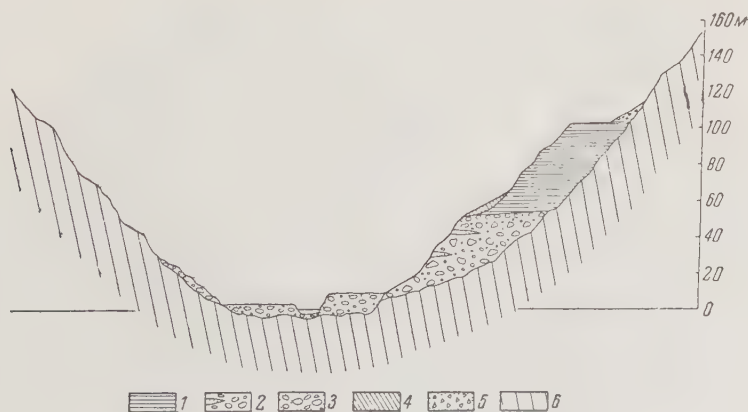


Fig. 4. Position of the horizontally bedded clays in the Chulyshman River valley, opposite the mouth of the Yelandu River:

1 -- horizontally bedded clays; 2 -- moraine with lenses of sandy loam; 3 -- river-valley boulder gravels and river-valley terrace; 4 -- clay talus; 5 -- shale talus; 6 -- shales ( $P_2$ ).

Table 2

Depth from which specimen was taken, m	Weight of fraction in percent				
	0.25 - 0.10 mm	0.10 - 0.05 mm	0.05 - 0.01 mm	0.01 - 0.005 mm	Less than 0.005 mm
12	0.05	5.61	56.70	23.26	14.38
21	0.02	3.34	5.16	3.85	87.63

by the close genetic connection between the horizontally bedded deposits and the degradation of the glaciers of the last glacial phase.

\* \* \*

Some attention must be devoted to a rather important question of considerable significance in principle in explaining the evolution of the glaciation -- the origin of the large-boulder deposits in the terraces.

In many valleys with terminal moraines of the last glacial phase, the contemporaneous super-floodplain terrace I, which is up to 50 m high near the moraines (in the Alash River valley), is made up of boulders and gravel (with large blocks) cemented by sand and grit (Figs. 6, 7).

The presence of large boulders and blocks in the terrace deposits has led certain investigators [4, 13, 30] to doubt that they are of

aqueous origin. It is usually considered that the terrace boulder conglomerate belongs to the penultimate or greatest glaciation and was eroded by ice-water streams during the last glaciation. The lack of clear divisions in the granulometric composition of the terrace deposits forces one to draw hypothetical boundaries for this maximum glaciation.

The present author's observations do not allow him to agree with this reconstruction of the maximum glaciation. The above-mentioned terrace deposits have a typically clear differentiation in their granulometric composition throughout a definite part of the valley. Thus, for example, as one moves downward along the Khemchik valley the sizes of the blocks and boulders and their percentage in the composition of the terrace deposits show a gradual decrease. Although 3 to 5 km below the terminal moraine one now and then encounters blocks with a diameter of 3 to 4 m, at the village of Baytal, 20 km from the terminal moraine, the greatest size of the blocks does not exceed 1.5 m.

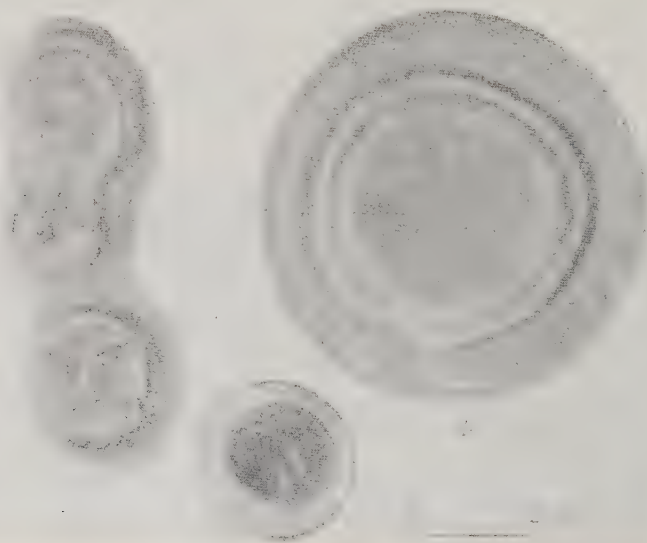


Fig. 5. Concretions from the lacustro-glacial horizontally bedded clays of the Chulyshman River valley (I) and the sandy loam of the Khemchik River valley (II)

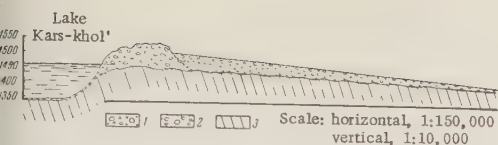


Fig. 6. Longitudinal profile of the upper part of the Alasha River valley.

1 -- moraine; 2 -- fluvioglacial boulder gravels; 3 -- Paleozoic shales.

30 km from the moraine the composition of the terrace is predominantly gravel and the maximum size of the boulders is 30 to 50 m. In addition, in moving away from the terminal moraine the degree of rounding of the boulder-gravel material increases. All this points to water as the major factor in the formation of these deposits.

Besides the clear differentiation in the particle size, the water transportation of the boulder and block material is also indicated by the relationship of the granulometric composition of the terrace deposits to the magnitude of the glacial basins and the hydrodynamic conditions of the discharge of meltwater from the glaciers during the last phase of glaciation. In this connection there is a very sharp contrast between the terrace deposits below the terminal moraines of glaciers that have emerged into the foothill area and those of valley glaciers. In the first case the composition of super-floodplain terrace I contains only a small percentage of boulders, and this mainly in the immediate vicinity of the terminal moraines. In the Arta-Shigetey valley, for example, boulders more than 1 m in diameter cannot be found at a distance of

one km from the moraine. The terminal moraines have a very distinct outer boundary, beyond which (outside super-floodplain terrace I) no traces of the introduction of morainal material may be observed; the moraines lie on pre-glacial proluvial and alluvial deposits. All this is associated with the lack in these glaciers of concentrated meltwater currents, inasmuch as these glaciers spread out for many kilometers over the relatively flat territory of the foothills.

A completely different composition is found in the terrace deposits below the terminal moraines of valley glaciers; this is especially clear in the above-cited example of the Khemchik valley. There is a characteristic correspondence between the volumes of the terminal moraines of the Khemchik valley and that of its tributary, the Chindozyrn River (Fig. 8). Although there is an enormous quantity of clastic material carried by the glacier in the Khemchik valley (this may be judged by the large number of deep cirques and glacial troughs in its basin), the amount contained in the terminal moraine is negligible. At the same time on the upper reaches of the Chindozyrn River, where the number of cirques feeding each glacial basin is about ten times less than in the Khemchik basin, the volume of the terminal moraines is several times greater than that of the Khemchik terminal moraine (although their thicknesses are about the same, 40 to 50 m). This striking disproportion between the volume of the terminal moraine deposits and the magnitudes of the basins can be explained only by the different conditions in the glacial ice-water streams. The extensive Khemchik glacial basin during the summer months must have produced a large amount of meltwater with a double strong current (since this is a



Fig. 7. Fluvioglacial terrace in the Khemchik River valley.

deep, narrow valley). The streams carried the morainal material from the glacier's snout and accumulated it along the bottom of the valley. The fact that in the Khemchik valley the narrow strips of terminal moraine have a typical hummocky morainal relief and a small thickness (40 to 50 m) is a sign of active transportation of glacial material directly away from the glacier during the entire time of its existence. With such currents of glacial meltwater, a thick terminal moraine could naturally not be formed in the narrow valley, whereas the glacial valleys of the Chindozyr River ended in the foothills and lacked such concentrated currents of glacial waters.

Since the energy of the glacial water streams was determined mainly by the magnitude of the glacial basin, the nature of the valley at the point where the glacier ended,

and its inclination, it is easy to explain the differences in the granulometric composition of the terrace deposits that are contemporaneous with the glaciation; these are observed in various valleys, sometimes side by side. This is confirmed by the example of more than forty glacial valleys with terminal moraines of the last phase of glaciation. Throughout the areas where the glaciers ended in the deep and narrow parts of valleys, even with small basins, the terraces contemporaneous with the glaciation are composed of large boulders directly adjacent to the terminal moraines. The greater the amount of coarse morainal material carried away from the glacier's snout, the smaller the volume of the terminal moraine, and vice versa. The currents of glacial meltwater were also of decisive importance in filling the terminal moraines with well-rounded boulders and cobbles; this is especially typical of the



Fig. 8. Sketch-map showing the relationships of the terminal moraines and glacial basins on the upper reaches of the Khemchik River.

1 -- glaciers of the last stage of glaciation; 2 -- cirques; 3 -- terminal moraines; 4 -- recessional moraines; 5 -- fluvioglacial terraces.

terminal moraines of valleys with great glacial basins, such as those of the Khemchik and Alash Rivers.

Thus the clear relationship between the granulometric composition of the terrace deposits and the hydrodynamics of the glacial water streams in the last phase of glaciation leaves no room for doubt that the terrace deposits are water-transported.

A no less important argument in support of this conclusion is the total absence of any signs of glaciation below the terminal moraines of the last glacial phase and above all, as noted above, the absence of boulders in the lateral moraine on the flat areas next to the valleys. This is shown by the existence, below the terminal moraines, of terraces older than the glaciation, including some of Eopleistocene age (in the Alash and Usty-Ishkin River valleys).

Other facts are also worthy of note. Terraces composed of great boulder material, especially granitic, may often be found in valleys where there is a complete absence of any transportation by glacial waters. In this regard valleys in which the rivers cut through areas of differing lithology are extremely indicative: as an example, one may take the valley of the Usty-Ishkin River, the left-hand tributary of the Khemchik. Throughout most of its length it is cut through Ordovician sandy shales. Granitic masses are intersected only in the uppermost and lowermost parts of the valley. On the upper reaches (here the river is called the Kuzhe) there was a small glacier (Fig. 1) which left a terminal moraine. Below this moraine the spread of granitic boulders may be seen only for several kilometers. The terraces in the middle part of the valley are composed of comparatively small-grained material, primarily of sandy shale composition; the granite is seen only in small pebbles. The nature of the deposits changes sharply where the river cuts through the granitic massif north of Lake Syut-Khol'. The first super-floodplain terrace, which occupies the whole bottom of the valley, is here made up of boulder and gravel deposits with blocks up to 2 m; there are also boulders in the higher terrace deposits. Below the massif, the granitic boulders may be traced for several kilometers down the valley, gradually decreasing in size. In this case these amount to typical mountain alluvial deposits whose granulometric composition varies within wide limits, depending on the lithology of the original material. As a rule, very coarse alluvium is formed by mountain streams from intrusive rocks, especially granitoids.

These specific features of stream deposits, in relation to the hydrodynamic conditions of

their formation, are confirmed by experimental data obtained by investigators of the dynamics of solid flow. V. N. Goncharov ([3], p. 290) gives a table showing the ratio of the size of transported grains of a homogeneous deposit to the velocity of the current (see Table 3).

Table 3<sup>1</sup>

Minimum Velocity Required to Begin Movement of the Particles of a Homogeneous Deposit in a Stream 1 m Deep

Grain size, mm	Velocity, m/sec	Grain size, mm	Velocity, m/sec
0.05	0.35	15	1.10
0.25	0.50	25	1.20
1.00	0.60	40	1.50
2.5	0.70	75	1.70
5.00	0.85	100	2.00
10.0	1.00	150	2.20
		200	2.40

<sup>1</sup>This table is taken from B. L. Rukhin's book *Osnovy Litologii* [Fundamentals of Lithology], 1953, p. 179.

The great increase in the magnitude of the transported grains with a small increase in the velocity, as shown in the Table, is very indicative. Thus, for example, to begin the movement of a boulder 20 cm in size, which is two times greater than gravel, an increase in the velocity of only 20 percent (2 m/sec and 2.4 m/sec) is required. This also accords with Eri's well known law, which states that the weight of the particles translated along the bottom of a stream is proportional to the sixth degree of the velocity of the current. Since the speeds of mountain streams may reach 5 to 8 m/sec, the presence of large boulders in the composition of mountain alluvium becomes understandable. When the velocity of the rivers increases by a ratio of 3:1 (assuming the velocity of a mountain stream to be 6 m/sec and of a plains river to be 2 m/sec), the weight of the transported fragments increases by 729:1. This may be seen in the following concrete example: if a granite pebble 10 cm in size which begins to move at a velocity of 2 m/sec weighs an average of 2 kg, the weights of boulders moved by the current will be, successively, 128 kg at 4 m/sec, 1,458 kg at 6 m/sec and 8,192 kg at 8 m/sec.

Thus the clear differentiation in the granulometric composition and the coarseness of the material cannot of themselves prove the glacial-water or much less the glacial origin of the deposits. Normal mountain alluvium, under the appropriate hydrodynamic conditions, has similar indices. Boulder and gravel deposits are consequently the same

natural product of mountain streams as sandy deposits are of plains rivers, as Ye. V. Shantser [29] has already pointed out.

All this shows the unreliability of the identification of fluvioglacial deposits in mountain and foothill areas, when the connection between the deposits and the terminal moraines cannot be traced. The lack of objective criteria, however, for distinguishing fluvioglacial from alluvial deposits according to the distance from the terminal moraines also makes the identification of the fluvioglacial deposits conditional to the same degree. In this connection, it would be expedient to apply Ye. V. Shantser's views [29] on the distinction between the concepts "fluvioglacial" and "alluvial" to mountain regions as well, reserving the term "fluvioglacial" only for the deposits of the most extensive parts of terraces, which were formed outside the periphery of large glaciers in the intermontane basins or in the broad basin areas of valleys. The sandy plains of the Kara-Khol and Mogun-Buren ravines and the Khemchik River (Fig. 1) are examples of such fluvioglacial deposits in Western Tuva.

It can be seen from the above that numerous mistakes in identifying glacial deposits in mountainous areas have resulted from an underestimation of the transporting power of water streams.<sup>1</sup> Such mistakes are also in no small measure due to the attempt to base the stratigraphy of the area on the usual scheme of four glaciations. Great difficulties in identifying glacial and associated deposits are still, of course, created by the fact that serious study of the conditions under which alluvium is formed have been made only for plains rivers [29].

The map of the last phase of glaciation (Fig. 1) shows that the semi-continental type of glaciation occurred mainly west of the Shapshal' Ridge and only partially to the east of it, in the northwestern part of Tuva; the valley glaciers are located mainly on the eastern slope of the Shapshal' Ridge.

The extensive development of semi-continental glaciation within the territory under consideration has been noted more than once. There is no universally accepted view, however, of the interrelationship between the semi-continental and the valley

glaciations. G. Grane [4], for example, has asserted that semi-continental ice sheets were extensively developed in the eastern and north-eastern parts of the Gorny Altay during the time of the last glaciation. V.P. Nekhoroshev [18, 19] also points out the semi-continental character of the last glaciation in the Prishapshal' part of the Altay. In contrast to G. Grane, however, V.P. Nekhoroshev attributes the morainal deposits of the Chulyshman-Bashkaus and Chulyshman-Kyga interstream areas to the penultimate glaciation, which in this area he considers to have been represented only by valley glaciers.

The interrelationships between the glacial deposits of valleys and interstream divides, and of catchment basins feeding the glaciers with the areas covered by semi-continental ice sheets, make it impossible to agree with such a subdivision and provide full confirmation of G. Grane's conclusions [4]. In areas of semi-continental glaciation, in numerous valleys (such as those of the Tashtu-Khol', Monaga, Kul'-Khema, Shavla, Chulyshman and other rivers) one and the same moraine may be traced clearly along small hanging valleys and sometimes directly along the slope from the bottoms of the valleys to the interstream divides. The evidence of glacial activity is no less clear (in the form of striated rocks, etc.); these traces are better preserved in the interstream areas than in the valleys. The curves of the valley banks are especially indicative: as a rule they are very smooth and gently shaped.

Numerous carved basins and glacial troughs from such glacial feeding sources as the Eri-Tayga and Kiyty massifs and the Shapshal' Ridge (in the southern part) open directly into relatively flat areas of the residual topography. Under these conditions, therefore, the glaciation from the very beginning must have developed from the valley into the semi-continental type, so that it appears quite impossible to introduce a break in time between the valley and the semi-continental types. In some cases the valley glaciers develop into semi-continental ice sheets when the ice fills the valleys and overflows them (as, for example, in the case of the Kul'-Khem -- Khemchik interstream divide). The main glaciation in this territory was nevertheless of the valley type.

The obvious asymmetry of the glaciation on the chief element in the mountain topography -- the Shapshal' Ridge -- is due both to the relief (to the extensive areas of residual topography west of this point) and to the climatic conditions, primarily the different amounts of precipitation on the slopes. The prevailing northwesterly and westerly winds caused most of the moisture to fall on the windward slopes of the ridge

<sup>1</sup>For this reason in some cases even the gravels in high terraces in the foothills have been taken as proofs of the greatest extent of the glaciation 16 .

and its spurs, with the result that here the glaciers were of considerable thickness and extent. Whereas on the eastern slope of the Shapshal' Ridge, for example, the maximal thickness of the glaciers in the last phase of glaciation was 600 to 700 m (in the Kozar and Khemchik valleys) in a length of 50 km, to the west of the ridge this thickness reached 1,200 to 1,500 m (in the Shavla and Chulyshman Valleys).<sup>1</sup> The length of the Chulyshman glacier was about 280 km. Differences in precipitation and in the air humidity produced great differences in the altitude of the snow line. Calculations indicate that, at the height of the last glacial phase, on the Sayan Ridge and southeast of Lake Teletskoye the snow line was at the level of about 1,800 to 1,900 m, whereas at the extreme southwest of Tuva, where there is glaciation today, the snow line was at the altitude of 2,700 to 2,800 m. At present the snow line in this area lies at the elevation of 3,400 m. Thus at the height of the last glacial phase it was some 600 to 700 m lower.

The glaciation of the latest phase, depending on the factors involved, thus ranged from the embryonic valley type to the extensive semi-continental. This is equally true of the next-to-the-last phase of glaciation, since there are no differences in principle in the character of the topography between these times.

The literature on the Altay-Sayan mountain region [13, 16, 21, 27] records the often-recurring view that the topography was reworked during the interglacial period. The so-called superimposed troughs are often pointed to as proofs of such a reworking or of considerable interglacial incision of the drainage system. In this scheme, the broad residual valleys are called ancient troughs. The cases in which these "ancient troughs" fail to coincide with the present drainage net are usually cited as evidence that the older glaciation developed under different geomorphologic conditions, as it were. And the fact that the younger erosional parts of the valleys are often incised into these ancient valleys and recarved by glaciers is supposed to serve as confirmation that there was considerable interglacial incision of the drainage system and subsequent valley glaciation.

It has been shown above that the partial rearrangement of the topography and the drainage system in the territory under

consideration had been taking place for a long time before the glaciation, primarily at the end of the Pliocene and beginning of the Eopleistocene. The broad valleys could not have been formed by glaciers, because of the nature of the latter's exaration -- the glaciers merely preserve such forms, as may easily be seen from the Eopleistocene and younger deposits contained in them (in the Ustu-Gimate and Kubadru valleys), so that they cannot be called "troughs." These valleys have a different character. They are parts of Tertiary river valleys (perhaps primarily of erosional and combined erosional-tectonic origin); this is confirmed by the presence of alluvial sediments of appropriate age (for example, Neogene carboniferous deposits in the Dzholukul' ravine). The incision of the drainage net, including the ancient valleys, took place long before the glaciation as already remarked above), and during the glacial period the incised parts of the valleys were reworked into troughs. The glaciers often did not occupy the valleys and covered the interstream areas instead (as in the Monaga, Chulyshman and other river valleys). All the troughs, regardless of whether they were cut into the plateaus of watersheds or into the bottoms of ancient river valleys, clearly contain one bend in the slope, corresponding to the area where the erosional-exarational surface meets the surface of the watershed slope or that of the bottom of the residual river valley. The local steps in the valley slopes that are sometimes encountered bear no relation to what is usually meant by superimposed glacial troughs.

The penultimate phase of glaciation may evidently be considered as coinciding in time with the maximal glaciation of the plains, and the last phase with Valday (Zyryan) glaciation. The great differences in the scales of the last and penultimate glacial phases between the mountain areas and the plains are to be explained by the continuing domical uplifts, which in some places are quite clearly marked. In the areas that contain Eopleistocene deposits, especially the outlying parts of the ridges, one may observe the relationships shown in Figure 2. The superimposed nature of the Pleistocene alluvial deposits testifies to the subsidence of the foothill areas at this time. This was followed by the uplift that caused some incision of the drainage system, and then by the development of glaciation. Similar interrelationships may also be observed in the adjoining areas to the east (in the Khule River valley and its exit from the Western Tannu-Ola ridge) and to the west (in the Kubadru River valley).

Only the increase in the absolute elevation of the region can explain the fact that the last and the penultimate glacial phases

<sup>1</sup>At the present time of weak glaciation, the Great Aletsh glacier in the Alps is 800 m thick, and the Fedchenko glacier in the Pamirs is 500 m thick.

are approximately equal in scale.<sup>1</sup> The existence of traces of only the last glaciation, and of uplift as a possible explanation of this peculiarity, have already been pointed out in the case of other mountainous regions [15].

The idea that the mountain glaciation was caused by the latest uplift of the mountains is considered to be incorrect. The mountain systems existed for a long time before the glaciation, but the latter was manifested only during a very limited and specific time interval and was caused by a general drop in temperatures over the whole planet that was due, apparently, to terrestrial factors.

The ancient glaciation in this region was very intensive. Enormous areas of the residual topography were covered by a fairly thick blanket of ice, which in the Dzhlukul' ravine, for example, reached a thickness of 400 m. The main catchment basins and points of origin of the glaciation were the peaks of the ridges and massifs. Nevertheless, when the snow line was rather low, especially in areas of semi-continental glaciation, the ice sheets developed even without such centers (on the Chulyshman-Bashkaus and Chulyshman-Kyga watersheds and in other places). The semi-continental ice sheets produced no essential changes in the relief; in fact they preserved extensive areas of the residual topography.

The activity of the valley glaciers, which was not limited to slight changes in the shape of the terrain, was quite different. The longitudinal profiles of the glacial valleys are extremely indicative: there is a clear relationship between the profile of the bottom of a tributary glacial valley and the relationship of its glacier to the trunk glacier. If the tributary glacier was of the same size as the main valley glacier (the shapes of the valleys being similar), there is no distinct step, or hanging valley, in the longitudinal profile of the tributary valley (as in the Shavla - Chulyshman valleys); if the tributary glacier was smaller, on the other hand, there was a hanging valley where it merged with the trunk glacier, and if it was larger, the trunk valley was left hanging above the tributary (as on the upper reaches of the Chel'-cha River in the Alash basin). The height of the steps varies from scores to hundreds of meters.

The large number of hanging valleys in the glaciated areas and their complete absence in the immediately adjacent unglaciated areas, which are identical in regard to their geologic structure and history, cannot be satisfactorily explained except on the basis of down-carving of the valleys by the glaciers. Serious works on glaciology produced both in the U.S.S.R. and in other countries (see P.A. Shumskiy's substantial paper and its bibliography, [31]) furnish the necessary material for understanding the mechanism of glacial exaration. From the standpoint of exaration, the temperature conditions in the bottom layers of glaciers are the most interesting ([31], p. 369).

The changes in topographic shapes caused by glacial activity are most extensive in the uppermost parts of ridges and massifs. Here the cirques are of huge size (as much as 1,000 m in depth in the Khemchik and Chulyshman basins). Their step-like character is easily seen, most of the cirques having two steps. All the cirques acted as accumulation basins for firn and ice during the last glacial phase, and there is no basis for distinguishing older and younger cirques. The older cirques may have been poorly developed, especially in Paleozoic shales and sandstones, when the formation of the cirques produced little change in the original shape of the funnels collecting water. Tarns are found only where the rocks at the core crop out, so that one may say that there was no cirque-and-step-forming stage of glaciation.

It must be noted that in the case of the territory under consideration the development of the glaciation (and its age) as recorded here agrees generally with the observations and conclusions of a number of investigators both of this region (I.G. Nordega and I.S. Gudilin) and of the mountain areas bordering on it (N.P. Ladokhin, [12]; G.F. Lunger-sauzen and O.A. Rakovets, [14]). Investigations over many years by a group of workers in the Department of Quaternary Geology of the Geological Institute of the Academy of Sciences of the U.S.S.R. have shown, on the example of an extensive area in the southern part of Eastern Siberia, which was not glaciated, that there was a single period of lowered temperatures corresponding to the second half of the Middle and to the Late Pleistocene [2, 22].

\* \* \*

Everything that has been said above may be summarized as follows:

The basic features of topography of Western Tuva and the eastern part of the Gorny

<sup>1</sup>Because of the uplifts, the mountain area within the ionosphere during the time of the last glacial phase must have remained the same size (or somewhat greater) as in the next to the last phase. There is no basis for assuming that there was any considerable increase in the precipitation during the last phase.

Altay are inherited from Eopleistocene times. Differential uplifts appeared very distinctly from Eopleistocene times. Differential uplifts appeared very distinctly after the deposition of carboniferous sediments containing flora of Miocene age -- that is, before and at the beginning of the Eopleistocene. These considerably elevated the ridges and produced some rearrangement in the drainage system.

Reliable evidences of glaciation have been found only for the second half of the Middle Pleistocene. Two phases of what was evidently a single glaciation have been noted, both of them being of about equal scale, so the vestiges preserved are mainly those of the last phase.

The character of the glaciation was determined mainly by the topography, whose general features and dissection at the beginning of the glacial stages were very similar to those of today. No essential rearrangement is observed to have taken place since the beginning of the glaciation.

The glaciation of both phases, depending on the topography and the climatic conditions, varied from incipient valley to extensive semi-continental. During the retreat of the glaciers of the past phase, large areas of "dead" ice were formed (especially in places of semi-continental glaciation); these produced extensive glacial ice-water formations -- eskers, kames, etc.

The horizontally bedded clay and sand deposits above, within and below moraines encountered in glacial valleys are fluvio-glacial formations dating from the retreat of the glaciers in the last phase, and cannot be used as evidence in the stratigraphic subdivision of the morainal series.

The terrace deposits with large boulders that occur extensively in mountain and foothill areas are fluvio-glacial and alluvial formations. The amounts and sizes of the boulders in them were determined mainly by the hydrodynamic characteristics of the meltwater streams. In the large glacial basins (the Khemchik and Alash) the meltwater streams had more energy than the present-day streams. This origin of the large-boulder deposits eliminates the possibility of reconstructing the history of the glaciations according to the presence of boulders in the terrace deposits.

## REFERENCES

1. Biske, G.S., OZY KARELI [THE ESKERS OF KARELIA]: Akademiya Nauk SSSR, 1955.
2. Vagengeym, E.A., NOVYYE DANNYYE O CHETVERTICHNOY FAUNE MLEKOPITAYUSHCHIKH YUGA SIBIRSKOY PLATFORMY [NEW INFORMATION ON THE MAMMALIAN FAUNA IN THE SOUTH OF THE SIBERIAN PLATFORM]: Trudy Mezhd. Soveshch. po Stratig. Sibiri, 1957.
3. Goncharov, V.N., DVIZHENIYE NANO-SOV [THE MOVEMENT OF ALLUVIAL DEPOSITS]: ONTI, 1938.
4. Grane, G.O., O LEDNIKOVOM PERIODE V RUSSKOM ALTAYE [THE ICE AGE IN THE RUSSIAN ALTAY]: Izvestiya Zap.-Sib. Otd. Russk. Geog. Obshchestva, t. 3, Vyp. 1-2, Omsk, 1916.
5. Gromov, V.I., PALEONTOLOGICHESKOYE I ARKHEOLOGICHESKOYE OBOSNOVANIYE STRATIGRAFIY KONTINENTAL'NYKH OTLOZHENIY CHETVERTICHNOGO PERIODA NA TERRITORII SSSR (MLEKOPITAYUSHCHIYE, PALEOLIT). [THE PALEONTOLOGICAL AND ARCHAEOLOGICAL BASIS FOR THE STRATIGRAPHY OF THE QUATERNARY CONTINENTAL DEPOSITS WITHIN THE TERRITORY OF THE U.S.S.R. (MAMMALIA, PALEOLITHIC)]: Trudy Instituta Geol. Nauk, Akademiya Nauk SSSR, Vyp. 64, 1948.
6. \_\_\_\_\_, STRATIGRAFICHESKAYA SKHEMA CHETVERTICHNYKH OTLOZHENIY SSSR I YEYE COPOSTAVLENIYE S ZARUBEZHNYMI SKHEMAMI [THE STRATIGRAPHY OF THE QUATERNARY DEPOSITS OF THE U.S.S.R. AND ITS CORRELATION WITH FOREIGN SYSTEMS]: Tez. Dokl. Vses. Mezhdud. Soveshch. Po Izuch. Chetvertichnogo Perioda, 1957.
7. Dubinkin, S.F., K VOPROSU O PENEPLANE ALTAYA [THE PROBLEM OF THE ALTAY PENEPLANE]: Vestnik Zap.-Sib. Geol. Upr. Vyp. 2, 1940.
8. Zaytsev, N.S., O PLIOTSENOVYKH OSADKAKH I MOLODYKH DVIZHENIYAKH V KHREBTE TANNU-OLA [THE PLIOCENE DEPOSITS AND THE LATE MOVEMENTS IN THE TANNU-OLA RIDGE]: Dokl., Akademiya Nauk SSSR, t. 57, no. 9, 1947.
9. Ivanovskiy, L.N., OB OSOBENNOSTYAKH DREVNEGO OLEDELENIYA YUGOVOSTOCHNOGO ALTAYA [SOME SPECIAL FEATURES OF THE ANCIENT GLACIATION IN THE SOUTHEASTERN ALTAY]: Trudy Tomsk. Gos. Universiteta, t. 133, 1956.

10. Kaletskaya, M.S., RAZVITIYE REL'YEFA SEVERO-VOSTOCHNOGO ALTAYA [THE DEVELOPMENT OF THE TOPOGRAPHY OF THE NORTHEASTERN ALTAY]: Trudy Institute Geog. Akademiyi Nauk SSSR, Vyp. 39, 1948.
11. Kuznetsov, V.A., TEKTONIKA ZAPADNOY TUVY NA STYKE S GORNYM ALTAYEM [THE TECTONICS OF WESTERN TIVA AT ITS JUNCTION WITH THE GORNY ALTAY]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol. no. 1, 1948.
12. Lakokhin, N.P. O DREVNE OLEDELENI BARGUZINSKOGO KHREBTA [THE ANCIENT GLACIATION OF THE BARGUZIN RIDGE]: Materialy Po Izuch. Proizv. Sil Buryat-Mongol'skoy ASSR, Chita, 1954.
13. Lebedeva, Z.A. OSNOVNYE CHERTY GEOLOGII TUVY [THE MAIN FEATURES OF THE GEOLOGY OF TIVA]: Trudy Mong. Komis. Akademiyi Nauk SSSR, no. 26, 1938.
14. Lungersauzen, G.F. and O.A. Rakovets, O GRANITSE TRETICHNOY I CHETVERTICHNOY SISTEM NA GORNOM ALTAYE [THE BOUNDARY BETWEEN THE TERTIARY AND QUATERNARY SYSTEMS IN THE GORNY ALTAY]: Tez. Dokl. Vses. Mezhdved. Soveshch. Po Izuch. Chetvertichnogo Perioda, 1957.
15. Markov, K.K., GEOMORFOLOGICHESKIY OCHERK PAMIRA I VAKHIN [OUTLINE OF THE GEOMORPHOLOGY OF THE PAMIRS AND THE VAKHINA MOUNTAINS]: Trudy Lednikovykh Eksp., t. 1, Leningrad, 1936.
16. Molchanov, I.A., NESKOL'KO SLOV O DREVNE OLEDELENI VOSTOCHNOGO SAYANA [A FEW REMARKS ON THE ANCIENT GLACIATION IN THE EASTERN SAYAN]: Trudy Komis. Po Izuch. Chetvertichnogo Perioda, t. 2, 1932.
17. Moskvitin, A.I., ALTAYSKIYE LEDOYEMY [THE ALTAY ICE-BASINS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol. no. 5, 1946.
18. Nekhoroshev, V.P., DREVNEYE OLEDELENIYE ALTAYA [THE ANCIENT GLACIATION IN THE ALTAY]: Trudy Komis. Po Izuch. Chetvertichnogo Vyp. 1, 1932.
19. \_\_\_\_\_, MATERIALY DLYA GEOLOGII GORNOGO ALTAYA [MATERIALS ON THE GEOLOGY OF THE GORNY ALTAY]: Trudy Vses. Geol. - Razved. Obyedin. Vyp. 177, 1932.
20. Obruchev, V.A., ALTAYSKIYE ETYUDY. II. O TEKTONIKE RUSSKOGO ALTAYA [ALTAYAN STUDIES. II. THE TECTONICS OF THE RUSSIAN ALTAY]: Zemlevedeniye, Kn. 3, 1915.
21. Postoyev, K.I., O SLEDAKH DREVNEGO OLEDELENIYA V YUGO-ZAPADNYKH SAYANAKH. [TRACES OF ANCIENT GLACIATION IN THE SOUTHWESTERN SAYAN]: Izvestiya Gorno-Geol. Obyedin. Vyp. 2-3, 1932.
22. Ravskiy, E.I., M.N. Alekseyev and N.S. Chebotareva K STRATIGRAFI VERKHNETRETICHNYKH I CHETVERTICHNYKH OTLOZHENIY YUZHNOY I VOSTOCHNOY CHASTI SIBIRSKOY PLATFORMY [THE STRATIGRAPHY OF THE UPPER TERTIARY AND QUATERNARY DEPOSITS OF THE SOUTHERN AND EASTERN PARTS OF THE SIBERIAN PLATFORM]: Trudy Mezhdved. Soveshch. Po Stratigr. Sibiri, 1957.
23. Radugin, K.V., GEOLOGICHESKIY OCHERK CHEMAL'SKOGO LISTA GORNOGO ALTAYA [AN OUTLINE OF THE GEOLOGY OF THE CHEMAL PLATE OF THE GORNY ALTAY]: Trudy Oyrotsk. Kompl. Eksp. Sov. Po Izuch. Proiz. Sil, Akademiya Nauk SSSR, t. 1, 1941.
24. Seliverstov, Yu. P., O PROISKHOZHDENII NARYMSKOY DEPRESSII NA ALTAYE [THE ORIGIN OF THE NARYM DEPRESSION IN THE ALTAY]: Materialy Vses. N.-I. Geol. In-Ta, Vyp. 19, 1956.
25. Semenov, A.I., K VOPROSU O VOZRASTE KRASNO-BURYKH GLIN YUGO-VOSTOCHNOY CHASTI RUDNOGO ALTAYA [THE PROBLEM OF THE AGE OF THE REDDISH-BROWN CLAYS IN THE SOUTHEASTERN PART OF THE RUDNOY ALTAY]: Materialy Vses. N.-I. Geol. In-ta, Obshch. Ser. Sb. 8, 1948.
26. Semikhatova, L.I., GOSUDARSTVENNYY ALTAYSKIY ZAPOVEDNIK [THE ALTAY STATE FOREST]: Zemlevedeniye, 5. 36, Vyp. 2, 1934.
27. Speranskiy, B.F. OSNOVNYE MOMENTY KAYNOZOYSKOY ISTORII YUGO-VOSTOCHNOGO ALTAYA [THE CHIEF PERIODS IN THE CENOZOIC HISTORY OF THE SOUTHEASTERN ALTAY]: Vestnik Zap.-Sib. Geol. Tresta, no. 5, 1937.
28. Tatarinov, P.M., V.A. Kuznetsov and K.S. Filatov, GEOLOGICHESKIYE ISSLEDOVANIYA V RAYONE AKTOV-

- RAKSKOGO MESTOROZHDENIYA AS-BESTA V VERKHOV'YAKH R. YENISEYA [GEOLOGIC INVESTIGATIONS IN THE AREA OF THE AKTOVRAS AS-BESTOS DEPOSIT ON THE UPPER REACHES OF THE YENISEY RIVER]: Trudy Tsent. N.-I. Geol.-Razved. In-ta, Vyp. 13, 1934.
9. Shantser, Ye. V., ALLYUVIY RAVNIN-NYKH REK UMERENNOGO POYASA I YEGO SNACHENIYE DLYA POZNANIYA ZAKONOMERNOSTEY STROYENIYA I FORMIROVANIYA ALLYUVIAL'NYKH SVIT [THE ALLUVIUM OF RIVERS FLOWING THROUGH PLAINS IN THE TEMPERATE ZONE AND ITS IMPORTANCE IN UNDERSTANDING THE LAWS GOVERNING THE STRUCTURE AND THE FORMATION OF ALLUVIAL SUITES]: Trudy In-ta Geol. Nauk, Akademiya Nauk SSSR, Vyp. 135, 1951.
0. Shorygina, L. D., K VOPROSU O STRATIGRAFICHESKOM RASCHLENENII CHETVERTICHNYKH OTLOZHENIY ZAPADNOY TUVY [THE PROBLEM OF THE STRATIGRAPHIC SUBDIVISION OF THE QUATERNARY DEPOSITS IN WESTERN TUVA]: Trudy Mezhd. Soveshch. Po Stratigr. Sibiri, 1947.
31. Shumskiy, P. A., OSNOVY STRUKTURNOGO LEDOVEDENIYA [FOUNDATIONS OF THE STUDY OF THE STRUCTURE OF GLACIERS]: Akademiya Nauk SSSR, 1955.
32. Shcherbakova, Ye. M., K VOPROSU OB ISTORII RAZVITIYA VOSTOCHNOGO SAYANA [THE PROBLEM OF THE HISTORY OF THE EASTERN SAYAN]: Trudy Komis. Po Izuch. Chetvertichnogo Perioda, t. 13, 1947.
33. Flint, R. F. THE STAGNATION AND DISSIPATION OF THE LAST ICE SHEET: Geographical Review, no. 1, 1929.
- Geological Institute of the U. S. S. R.  
Academy of Sciences,  
Moscow
- Received November 20, 1957

## BRIEF COMMUNICATIONS

### TYPES OF DEEP FAULTS ON THE BOTTOMS OF THE OCEANS

by D. G. Panov

Investigations by A.V. Peyve and N.S. Shatskiy [8, 9, 12, 13, 14] have shown the importance of the role played by deep faults in the formation of the major structural differences in the earth's crust. It has been established that deep faults had a decisive effect on the structural history of the platform and geosynclinal regions of the continents. Movements during the latest stages of geologic history along the lines of deep faults also produced the major features of the surface relief of the dry lands. N.S. Shatskiy [15] has determined the distribution of deep faults over the surface of the planet, in terms of a system of orthogonal and diagonal lines, on the basis of which it may be suggested that these deep faults are extensively distributed over the ocean bottom and are an important factor in the morphology of the world's oceans. The data available at the present time support this assumption.

Several types of deep faults, which are clearly reflected in the submarine topography may be distinguished on the bottoms of the world's oceans. Tectonic dislocations over most of the ocean bottom are poorly hidden by accumulations of sediments, so that the lines of the deep faults are clearly reflected in the relief of the ocean bottom.

The following types of deep faults may be distinguished at the present time: 1) those in the continental slopes, and 2) those at the bottoms of the ocean basins.

1. Deep faults in the area of the continental slope. The continental slope is often considered to be a transitional zone between the structures of the continents and those of the oceans [10]. The sharp changes in the distribution of gravitational anomalies and the high degree of present-day seismic activity of the tectonic conditions within the limits of the continental slope during the present period. It is quite possible that this present intensity of tectonic stresses within the continental slope is associated with Quaternary tectonic uplift of the continents and subsidence of the ocean basins [5].

There are two types of deep faults on the continental slope: open and concealed. Open faults are most clearly reflected in the morphology of the continental slope, since they are manifested in the great lateral extent (thousands of kilometers) and the great height (thousands of meters) of the steps in the continental slope. One example is the scarp in the continental slope of the Pacific coast of North America; this scarp extends from the Gulf of Alaska to California, with a length of 4800 km and a height of 3000 m. A.Eardley [3] believes that it is formed by young faults. In addition to this fault, which runs parallel to the folded structures, there are known to be numerous transverse faults in this area. These produce a complicated submarine surface relief, dividing the continental slope into a system of uplifted and unequally down-faulted sections which are cut through by a large number of canyons. On the west coast of South America the continental slope reaches the greatest known height of 7000 m [16]. There is known to be a very long scarp in the continental slope on the shore of Brazil. A large and steep continental slope formed by young faults is also to be found in the Central Polar basin [7].

Block faulting of the continental slope, associated with recent tectonic disintegration, has also been encountered in the Antarctic [2]. The morphology of certain individual areas of this region indicate that it contains a possible system of step-like displacements along fault lines. Steeply dipping scarps in the continental slope are known to extend for great distances. The concealed faults in this region are revealed in the formation of a continental fold. The flexure type of continental slope may be seen clearly in the Atlantic Ocean, on the coasts of Western Europe and North America.

Geophysical investigations have shown that the folded basement within a slope of this type is broken up into a system of unequally displaced blocks that form the basement of the flexure at the foot of the slope. In this respect the structure of the slope is similar to that of the flexures at the borders of the continents. At the foot of the slope there is a distinct synclinal flexure filled to a considerable depth with unconsolidated

deposits [18, 19]. According to Sheppard's information [16], the flexure at the foot of the slope extends for 50 percent of its length. In some individual parts it takes the form of a trough, which is not filled with sediments; this may be an indication that the trough was formed not long ago, as a result of the recent subsidence of the continental flexure. The recent date of the subsidence of the continental flexure is also evidenced by the worldwide distribution of submarine valleys, whose formation is connected with the development and subsidence of the continental flexure [4]. The flexural type of continental slope predominates in the oceans of the world.

2. Deep faults in the bottoms of the ocean basins. In the bottoms of the ocean basins, deep faults are associated with three different kinds of surfaces of the ocean bottom: submarine abyssal plains, submarine ridges and submarine abyssal trenches.

Deep faults in submarine ridges are known from the example of the Mid-Atlantic Ridge. Herrman (1948) pointed out the connection between the Mid-Atlantic Ridge and fault lines extending for great distances; more recently B. Heezen [20] showed that this submarine ridge is broken up into rift valleys and raised blocks between them, forming a structure similar to that of the zone of rift faults in Eastern Africa. The amplitude of the displacements in the Mid-Atlantic Ridge is 1800 m or more. The distinct linearity of the submarine ridges in the ocean, along with their concentrated seismic activity in the present geologic period, indicates that they probably follow the lines of deep faults extending for enormous distances. Ya. Gakkel' [1] has shown the connection between the Lomonosov submarine ridge and the lines of deep faults.

In the submarine abyssal plains, deep faults form zones of great extent in which the submarine relief is sharply dissected and in which there are areas of young volcanic topography. In the eastern part of the Pacific Ocean, H. Menard [21] has distinguished several zones of such broken-up areas associated with deep faults extending for great distances. Of these, the Mendocino zone of faults extends for more than 2000 m, the displacement of the ocean bottom within it being as great as 3000 m. The Murray zone, which has a complex topography dissected by faults, stretches from the North American coast to the Hawaiian Islands. The fault zones farther to the south -- the Clerion and the Clipperton zones -- have a similar structure and topography.

Besides those mentioned above, there are

probably many deep faults distributed throughout the western and central parts of the Pacific Ocean which have also produced a submarine surface relief of uplifted blocks. The complex dissection of the submarine abyssal plains that has been revealed by the most recent investigations in other oceans as well is also probably connected with the lines of deep faults.

The connection between the well-known submarine abyssal trenches and the lines of deep faults has been established; it is confirmed by the distribution of the foci of deep-seated earthquakes [17]. The sides of the submarine abyssal trenches have step-like profiles, and together with the deep fault lines form complex zones of dissection and subsidence of the earth's crust. The great depth of the sediments in the trenches, and the fact that the Mohorovicic discontinuity here occurs at greater depth than beneath the other parts of the ocean bottom, indicates a close connection between the formation of the submarine trenches and the structure of the substances in the mantle of the earth. Possibly the deep faults here extend far into the center of the earth's globe.

The faults in the bottoms of the oceans are distinguished by their greater extent and more recent tectonic activity, as compared to the deep faults in the continents. There is full basis for calling them oceanic faults of planetary scope, since they determine the greatest planetary features of the structure and relief of the ocean bottom.

The fact that the ocean platforms are bordered by lines of deep faults shows the general similarity between the structures of the continental and oceanic portions of the earth's crust. The differences in structure and history between the oceans and the continents may have been caused by processes taking place in the depths of the globe, in the mantle of the earth.

## REFERENCES

1. Gakkel', Ya.Ya., *NAUKA I OSVOYENIYE ARKTIKI [THE SCIENTIFIC STUDY AND THE EXPLOITATION OF THE ARCTIC]*; Morsk. Transport, 1957.
2. Zhivago, A.V. and A.P. Lisitsyn, *NOVYYE DANNYYE O REL'YEFE DNA I OSADKAKH MOREY VOSTOCHNOY ANTARKTIKI [NEW INFORMATION ON THE DEPOSITS AND RELIEF OF THE BOTTOM OF THE EASTERN ARCTIC OCEAN]*; Izvestiya, Akademya Nauk SSSR, Ser. Geogr., No. 1, 1957.

3. Eardley, A., STRUKTURNAYA GEOLOGIYA SEVERNOY AMERIKI [THE STRUCTURAL GEOLOGY OF NORTH AMERICA]: Izdatel'stvo In. Lit., 1954.
4. Muratov, M.V., ISTORIYA TEKTONICHESKOGO RAZVITIYA GLUBOKOY VPADINY CHERNOGO MORYA I YEYE VOZMOZHNOYE PROISKHOZHDENIYE [THE TECTONIC HISTORY AND THE POSSIBLE ORIGIN OF THE DEEP BASIN IN THE BLACK SEA]: Byull. Mosk. O-va Ispyt. Prirody, t. 30, No. 5, 1955.
5. Nikolayev, N.I., RAZVITIYE STRUKTURY ZEMNOY KORY I YEYE REL'YEFA PO DANNYM NEOTEKTONIKI [HISTORY OF THE STRUCTURE OF THE EARTH'S CRUST AND ITS SURFACE RELIEF ACCORDING TO DATA ON QUATERNARY GEOTECTONICS]: Sov. Geologiya, t. 48, 1955.
6. Panov, D.G., NEKOTORYYE OSOBENOSTI TEKTONIKI KRAYEVYKH CHASTEY TIKHOOKEANSKOY PLATFORMY [SOME PECULIAR TECTONIC FEATURES OF THE BORDERS OF THE PACIFIC OCEAN PLATFORM]: Doklady, Akademiya Nauk SSSR, t. 115, No. 1, 1957.
7. \_\_\_\_\_, TEKTONIKA I PROISKHOZHDENIYE TSENTRAL'NOGO POLYARNOGO BASSEYNA [THE ORIGIN AND THE TECTONICS OF THE CENTRAL POLAR BASIN]: Byull. Mosk. O-va Ispyt. Prirody, Otd. Geol., t. 32, Vyp. 1, 1957.
8. Peyve, A.V., GLUBINNYE RAZLOMY V GEOSINKLINAL'NYKH OBLASTYAKH [DEEP FAULTS IN GEOSYNCLINAL REGIONS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 5, 1945.
9. \_\_\_\_\_, OBSHCAYA KHARAKTERISTIKA, KLASSIFIKATSIYA I PROSTRANSTVENNOYE RASPOLOZHENIYE GLUBINNYKH RAZLOMOV. GLAVNEYSHIYE TIPY GLUBINNYKH RAZLOMOV [THE GENERAL CHARACTERISTICS, THE CLASSIFICATION AND THE DISTRIBUTION OF DEEP FAULTS. THE MAIN TYPES OF DEEP FAULTS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 1, 1956.
10. Khain, V.Ye. and YE.YE. Milanovskiy, OSNOVNYE CHERTY SOVREMENNOGO REL'YEFA ZEMNOY POVERKHNOSTI I NEOTEKTONIKA [THE CHIEF FEATURES OF THE PRESENT RELIEF OF THE EARTH'S SURFACE AND THE STUDY OF QUATERNARY TECTONICS]: Byull. Mosk. O-va Ispyt. Prirody, Otd. Geol., t. 31, No. 3-4, 1956.
11. Shatskiy, N.S., GIPOTEZA WEGENERA I GEOSINKLINALI [GEOSYNCLINES AND WEGENER'S HYPOTHESIS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 4, 1946.
12. \_\_\_\_\_, OSNOVNYE CHERTY STROYENIYA I RAZVITIYA VOSTOCHNOYEYUROPEYSKOY PLATFORMY. SRAVNITEL'NAYA TEKTONIKA DREVNYKH PLATFORM [THE MAIN FEATURES OF THE STRUCTURE AND HISTORY OF THE EASTERN EUROPEAN PLATFORM. COMPARATIVE TECTONICS OF ANCIENT PLATFORMS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 1, 1946.
13. \_\_\_\_\_, O NOVOY TEKTONICHESKOY KARTE SSHA (KRITICHESKIY ANALIZ) [A NEW TECTONIC MAP OF THE USA (A CRITICAL ANALYSIS)]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 5, 1947.
14. \_\_\_\_\_, O GLUBINNYKH DISLOKATSIYAKH, OKHVATYVAYUSHCHIKH I PLATFORMY I SKLADCHATYYE OBLASTI (POVOLZH'YE I KAVKAZ). SRAVNITEL'NAYA TEKTONIKA DREVNYKH PLATFORM [DEEP-SEATED DISLOCATIONS ENCOMPASSING BOTH PLATFORMS AND FOLDED REGIONS (THE VOLGA AREA AND THE CAUCASUS). COMPARATIVE TECTONICS OF ANCIENT PLATFORMS]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 5, 1948.
15. \_\_\_\_\_, O PROISKHOZHDENIY PACHELMSKOGO PROGIBA. SRAVNITEL'NAYA TEKTONIKA DREVNYKH PLATFORM [THE ORIGIN OF THE PACHELM SYNCLINAL FLEXURE. COMPARATIVE TECTONICS OF ANCIENT PLATFORMS]: Byull. Mosk. O-va Ispyt. Prirody, Otd. Geol., t. 30, No. 5, 1955.
16. Sheppard, F., GEOLOGIYA MORYA [MARINE GEOLOGY]: Izdatel'stvo In. Lit., 1951.
17. Benioff, H., OROGENESIS AND DEEP CRUSTAL STRUCTURE -- ADDITIONAL EVIDENCE FROM SEISMOLOGY: Bull. Geol. Soc. Am., Vol. 65, No. 5, 1954.
18. Bentley, Ch. and J.L. Worzel, GEOPHYSICAL INVESTIGATIONS IN THE EMERGED AND SUBMERGED

ATLANTIC COASTAL PLAIN: *Bull. Geol. Soc. Am.*, Vol. 67, No. 1, 1956.

NORTHWESTERN PACIFIC BASIN AND THE WEST COAST OF NORTH AMERICA: *Bull. Geol. Soc. Am.*, Vol. 66, No. 9, 1955.

19. Ewing, M., A.F. Crary and H.M. Rutherford, *GEOPHYSICAL INVESTIGATIONS IN THE EMERGED AND SUBMERGED ATLANTIC COASTAL PLAIN*: *Bull. Geol. Soc. Am.*, Vol. 48, No. 6, 1937.

22. Press, F. and Beckmann, *GEOPHYSICAL INVESTIGATIONS IN THE EMERGED AND SUBMERGED ATLANTIC COASTAL PLAIN*: *Bull. Geol. Soc. Am.*, Vol. 63, No. 3, 1954.

20. Heezen, B.C., *OUTLINE OF NORTH ATLANTIC DEEP-SEA GEOMORPHOLOGY*: *Bull. Geol. Soc. Am.*, Vol. 67, No. 12, p. 2, 1956.

State University of  
Rostov-on-Don

21. Menard, H., *DEFORMATION OF THE*

Received February 6, 1958

\* \* \* \* \*

# THE PROBLEM OF THE GENESIS AND THE AGE OF THE DINOSAUR STRATUM IN SOUTHEASTERN BET-PAK-DALA

by V.I. Yeliseyev

A peculiar feature of some of the districts of Central Asia and Kazakhstan is the accumulation of large quantities of dinosaur bone fragments, which in most cases occur in coarse gravel conglomerates. Such districts are the Bissekta spring area in the Kyzyl-Kum desert (100 km southwest of Lake Kuchka-Tengiz), Bozaba on the right bank of the Chu River, 90 km below the village of Gulyayevka, Kok-Muynak in the central part of the Boyamskiy gap, Karaya on the left bank of the Il' River, the area northwest of the stations of Iliysk, Karacheku and Kalkan on the right bank of the Il' River and Lake Tuz-Kul' in the eastern foothills of the Kara-Tau, Sary-Agach, and Dzhilga Ridges in the Tashkent district.

I.A. Yefremov, the famous "dinosaur hunter", has come to the conclusion in a number of articles [4, 6] that all these accumulations of dinosaur remains are of secondary occurrence, resulting from the erosion of Upper Cretaceous continental deposits and their redeposition in Eocene times. The main argument put forth by I.A. Yefremov in support of this conclusion is the great degree of fracturing, rounding, cracking and weathering of the bones in almost all of the deposits, with the exception of the Bissekta deposit and that of the Tashkent district, which have been found to contain well preserved bones (although they are shot through with cracks) and small quantities of rounded bone fragments. "The sec-

ondary occurrence<sup>1</sup> of the bone material", writes I.A. Yefremov [16], pp. 47-48), "is proved beyond a doubt by the condition of the bones and the nature of their fossilization. The bones bear traces of weathering, fracturing and wear and tear that have undoubtedly taken place after their fossilization -- that is, when the bones had already been petrified and the diagenesis and lithification of the bone-bearing rock had been completed. Such great damage to the huge dinosaur bones could have been done only by powerful streams, and then only when the bones were sufficiently brittle, some time after the bony material had been completely fossilized. Other indications -- the helter-skelter mingling of the bones of the most varied types of animals, the lack of any biological or hydro-mechanical sorting of the remains as would be expected in the case of deposits occurring in their place of origin, the total absence of any complete skeletal elements and the damages to the surfaces of the bones -- provide full confirmation of the erosion and destruction of the original deposits."

I.A. Yefremov considers the deposits that contain dinosaur bones to be proluvial, occurring "as a result of the erosion of the original Upper Cretaceous deltaic facies." The good state of preservation of the bony material and the small amounts of rounded bones in the Bissekta-Tashkent district deposits, in his opinion, "are evidence that the erosion was done by a great amount of water, which

<sup>1</sup>The article used the term "secondary importance" which, apparently, is a misprint.

covered the areas being eroded to a great depth so that they were not exposed to the air. The process of erosion was of extremely long duration and took place under the conditions of a steady decrease in the force of the currents, ending in the deposition of red cross-bedded deltaic sands" [6], p. 48).

In regard to the origin of the remaining deposits, characterized by the great fragmentation of their bones and a large percentage of rounded bones, he writes: "The dinosaur deposits in their original sites were, after fossilization, exposed to the air and subjected to weathering and erosion which totally removed the rocks that had contained them and in their place left only the bones of dinosaurs, as being the largest and heaviest fraction. Thereafter the dinosaur bones were moved and redeposited by streams of great force, which deposited coarse gravel at the same time. The dinosaur bones in the proluvial deposits are thus equivalent to the gravel of the conglomerates that contain them and are, as already noted, the residual fraction of the totally destroyed older sediments that had contained the original bone deposits" [6], p. 48).

The article, however, cites no proofs in support of his conclusions. Moreover the small percentage of rounded bones in the Bissekta-Tashkent district deposits are a clear contradiction of I. A. Yefremov's assertion that the erosion was of long duration and took place under a large amount of water.

The present author's investigations in the Bozaba district (the southeastern part of the Bet-Pak-Dala) have shown that the deposits containing the dinosaur bones and trunks of petrified wood are not of proluvial, but of marine littoral origin. The coastal marine origin of the bone-bearing gravels of Bozaba is proved by the occasional occurrence of sharks' teeth and the presence of limestones in the composition of the deposits, the density of the gravels and the great extent of the territory occupied by the bone-bearing gravels.

The following species were collected by the present author for the first time in these deposits: *Scapanorhynchus raphiodon* Ag., *Sc. subulata* Ag., *Sc. raphiodon* Wood, *Sc. gigas* Wood, indicating that the rocks containing them are of Santonian age (identifications and conclusion by L. S. Glikman). L. S. Glikman, moreover, states that the sharks' teeth show no traces of rounding and that they cannot have been reburied.

There are no less convincing proofs (according to the literature) of the coastal

marine origin of the dinosaur deposits in the Tashkent district. Here the bone-bearing beds contain large numbers of sharks' teeth, bony fish vertebrae and gastropod and pelycypod shells. G. I. Belen'kiy [1] gives the following list of marine fauna in the discharge from the Tas-Kotan and Alym-Tau mountains, occurring in the cross-bedded calcarenites along with dinosaur bones and petrified tree trunks: *Crassatella* cf. *regularis* d'Orb., *Pectunculus jaxartensis* Rom. (*Limopsis calvus* Sow.), *Natica subrugosa* d'Orb., *Pecten elongatus* Lam., *Protocardium semidecussatum* Rom., *Caprotina* sp. (*C. semistriata* d'Orb.), *Turritella* sp., *Cardium* sp., *C.* cf. *productum* Sow., *Cucullaea* sp.

The existence of large quantities of marine fauna in the bone-bearing beds of the Tashkent district, the lithologic composition of the dinosaur stratum (sandstones, calcarenites, limestones and conglomerates) and the greater thickness of the bone layer (about 30 m) as compared to its thickness in the Bozaba district (about 6 m) all indicate that the dinosaurs of the Tashkent district were buried in a part of the sea that was deeper than that of the Bozaba district.

The corpses of the dinosaurs that had been buried in the coastal zone of the sea in the Bozaba district were, of course, subjected to the intensive destructive action of the waves and were separated into individual members, mingled in disorder and broken into fragments; almost all the bone fragments were rounded. The dinosaur corpses buried in the deeper part of the sea, in the Tashkent area,<sup>1</sup> were also broken up and mixed, but the rounding of their bone fragments had apparently merely begun when it quickly came to an end through the incorporation of this marine basin into the continent;<sup>2</sup> the result was that the dinosaur bones ceased to be subjected to the wave action. This is the reason why there are so few strongly rounded bones in this deposit.

It becomes obvious from what has been said above that the dinosaur bones were fossilized after being broken up in the surf zone, and that the bones of the Bozaba and Tashkent districts are in their place of origin rather than being redeposited from older, Upper Cretaceous deltaic deposits.

<sup>1</sup>But still littoral, as shown by the close intermingling of marine and terrestrial fauna and flora.

<sup>2</sup>This is indicated by the overlying Darbazin suite, which is made up of typical marine facies with numerous marine fauna.

The stratigraphic position of the dinosaur stratum in the Tashkent deposit irrefutably confirms the conclusion that the bones they contain are in their original place of occurrence. Not a single investigator of this district places the dinosaur stratum later than the Turonian in age. B. A. Borneman, [2], for instance, considers the age of the dinosaur stratum to be Turonian; Ye. V. Ivanov [7] and N. Ye. Minakova [8] consider it to be Cenomanian. Recent detailed investigations of the Cretaceous in the Tashkent area by G. A. Belen'kiy have led him to find that "stratigraphically above the bed with the dinosaur bones lie deposits containing Turonian and Cenomanian fauna (of the Lower and Middle Darbazin stage)" and "to express himself in favor of the Turonian age of the dinosaur stratum" ([1], p. 78). M. Ye. Voskoboynikov [3], for the eastern part of the Ural area, cites a list of pangolins (identified by V. S. Bazhanov) indicating that the rocks in which they occur are of Early Senonian (Coniacian) age. V. I. Samoyurov [11] assigns these same deposits with the dinosaur bones to the Santonian stage.

The age of the dinosaur stratum most probably differs in different places, decreasing in age from the Bissekta-Tashkent district toward the north and east -- that is, in the direction of the sea's advance.

What was the ultimate fate of the dinosaur bones buried in the sediments of the Upper Cretaceous sea? It appears that this differed in the various deposits, especially between those of the Tashkent area on the one hand and those of the Bozaba district on the other. In the Tashkent district, marine conditions continued to prevail after the bones had been buried. Paleogene marine sediments covered the Upper Cretaceous dinosaur deposits and protected them from the action of atmospheric weathering agents. It is because of this that the bones of the Tashkent district are in a good state of preservation, and not because "the erosion took place under large quantities of water", as I. A. Yefremov has suggested.

In the Bozaba district, marine conditions did not reappear after the retreat of the Upper Cretaceous sea; here, in the surroundings of a flatlands topography, continental conditions predominated. Since they were lying at a small depth below the surface, the dinosaur bones and the deposits containing them began to be intensively weathered. The bone-bearing gravel conglomerates, sands and sandstones of the Bozaba district were kaolinized, and the pebbles in these unstable rocks were altered to clay. In essence, these deposits represent a weathered crust preserved from Paleogene times to the present day. This weathering,

according to K. V. Nikiforova [9], took place in the Eocene, as shown by the occurrence, above these deposits and farther to the west, of the Late Eocene Saksaul' suite, which bears no traces of kaolinized weathering. This fact also explains the absence of any continental Eocene deposits in the territory of Kazakhstan and Central Asia. There was no "large-scale" erosion, whose evidence, according to I. A. Yefremov, is the dinosaur conglomerates, in the Eocene; during this time, on the contrary, the flat surface of the former bottom of the Upper Cretaceous sea was subjected to chemical weathering and the formation of a weathered crust, whereas erosional activity was totally or almost totally lacking.

There was erosion within the territory of Central Asia and Kazakhstan only at the end of the Late Oligocene. As a result of this and later cycles of erosion and deposition, the dinosaur stratum of the Tashkent district was freed of its overlying Paleogene marine deposits and partially subjected to erosion. The dinosaur-bone deposits of the Bozaba and other districts, which were not protected by a mantle of younger sediments, underwent a greater degree of erosion. This is especially true of the Kok-Muynak deposits (in the center of the Boyamskiy district), which were located in an area of intensive Neogene-Quaternary uplift. Thus it was a combination of tectonic movements and erosion that caused "the occurrence of the deposits of the second type [all the above-enumerated deposits, with the exception of those in the Bissekta and Tashkent districts. -- V. Ye.] as isolated islands and massifs" ([6], p. 48).

All the facts set forth above lead the present author to conclude that the dinosaur deposits of the Bozaba and Tashkent districts are primary and in their original place of occurrence in the littoral zone of the Upper Cretaceous sea, and that I. A. Yefremov's conclusions regarding their secondary occurrence, their erosion and the destruction of the bones by powerful currents after fossilization are mistaken.

It must also be added that, up to the most recent time, there had been no finds of more or less complete skeletal parts, or even whole individual bones of dinosaurs, throughout the enormous territory of Kazakhstan and Central Asia, that might indicate their occurrence in the place of origin. Recently, however, this argument also collapsed when in 1957 the Kazakhstan expedition of the Paleontological Institute of the Academy of Sciences of the U. S. S. R. discovered Upper Cretaceous dinosaurs *in situ* in the red-colored clays about 100 km north of the village of Dzhusala (near the Dzhusala-Karsakpay road).<sup>1</sup>

<sup>1</sup> The author obtained this information and the permission to publish it in a conversation with A. K. Rozhdestvenskiy, Ye. I. Belyayeva and B. A. Trofimov, to whom he wishes to express his deep gratitude.

REFERENCES

1. Belen'kiy, G. A., STRATIGRAFIYA MELOVYKH OTLOZHENIY PRITASH-KENTSKIKH CHULEY [STRATIGRAPHY OF THE CRETACEOUS DEPOSITS OF THE TASHKENT CHULYA AREAS]: Trudy Sredneaz. Un-ta, Nov. Ser., Vyp. 13, Kn. 6, 1955.
2. Borneman, B. A., MELOVYYE OTLOZHENIYA YUGO-VOSTOKA SREDNEY AZII [THE CRETACEOUS DEPOSITS OF THE SOUTHEASTERN PART OF CENTRAL ASIA]: Izd. Uzb. Fil., Akademiya Nauk SSSR, 1940.
3. Voskoboynikov, M. Ye., MELOVYYE OTLOZHENIYA VOSTOCHNOGO PRIARAL'YA [THE CRETACEOUS DEPOSITS OF THE EASTERN PART OF THE ARAL REGION]: Doklady, Akademiya Nauk SSSR, t. 90, No. 5, 1953.
4. Yefremov, I. A., DINOZAVRY V KRASNOSVETNOY TOLSHCHE SREDNEY AZII [THE DINOSAURS IN THE RED-BED SERIES OF CENTRAL ASIA]: Trudy Paleont. In-ta, Akademiya Nauk SSSR, t. 1, 1931.
5. \_\_\_\_\_, DVA POLYA SMERTI MINUVSHIKH GEOLOGICHESKIKH EPOKH [TWO BURIAL FIELDS OF PAST GEOLOGIC EPOCHS]: Priroda, No. 7, 1933.
6. \_\_\_\_\_, DINOZAVROVYY GORIZONT SREDNEY AZII I NEKOTORYYE VOPROSY STRATIGRAFII [SOME STRATIGRAPHIC PROBLEMS CONNECTED WITH THE DINOSAUR STRATUM OF CENTRAL ASIA]: Izvestiya, Akademiya Nauk SSSR, Ser. Geol., No. 3, 1944.
7. Ivanov, Ye. V., GIDROGEOLOGICHESKIYE ISSLEDOVANIYA SEVERNOY CHASTI TASHKENTSKOGO UYEZDA V 1923 G. [HYDROGEOLOGIC INVESTIGATIONS IN THE NORTHERN PART OF THE TASHKENT DISTRICT IN 1923]: Izd. Upr. Vodn. Kh-va Sred. Azii, 1926.
8. Minakova, N. Ye., K STRATIGRAFI MELOVYKH I TRETICHNYKH OTLOZHENIY CHULEY [ON THE STRATIGRAPHY OF THE CRETACEOUS AND TERTIARY DEPOSITS OF THE CHULYAS]: Izd. Uzb. Fil., Akademiya Nauk SSSR, 1941.
9. Nikiforova, K. V., O VOZRASTE KORY VYVETRIVANIYA TSENTRAL'NOGO KAZAKSTANA. KORA VYVETRIVANIYA [THE AGE OF THE MANTLE OF WEATHERED ROCK IN CENTRAL KAZAKHSTAN. THE MANTLE OF WEATHERED ROCK]: No. 2, Akademiya Nauk SSSR, 1956.
10. Ryabinin, A. N., FAUNA POZVONOCHNYKH IZ VERKHNEGO MELA YUZNOGO KAZAKHSTANA [THE VERTEBRATES IN THE UPPER CRETACEOUS OF SOUTHERN KAZAKHSTAN]: Trudy Tsentr. N.-I. Geol.-Razved. In-ta (TsNIGRI), Vyp. 118, 1939.
11. Samodurov, V. I., STRATIGRAFIYA MEZOZOYSKIKH OTLOZHENIY RAYON NIZOV'YEV R. SYR-DAR'I [THE STRATIGRAPHY OF THE MESOZOIC DEPOSITS ON THE LOWER REACHES OF THE RIVER SYR-DARYA]: Byull. Mosk. O-va Ispyt. Prirody, t. 60, Otd. Geol., Vyp. 3, 1955.

Geological Institute, U.S.S.R.

Academy of Sciences, Moscow.

Received April 22, 1957

AWARD OF THE LENIN PRIZE IN 1958 TO  
ACADEMICIAN A.G. BETEKHTIN,  
ACADEMICIAN A.N. ZAVARITSKIY,  
ACADEMICIAN D.S. KORZHINSKIY AND  
ASSOCIATE MEMBER OF THE ACADEMY  
OF SCIENCES OF THE USSR  
V.A. NIKOLAYEV

It has been a source of deep satisfaction for Soviet geologists to find, among the winners of the Lenin Prize in 1958, the names of some of the greatest investigators in the field of ore formation -- Academicians A.G. Betekhtin, A.N. Zavaritskiy (awarded posthumously), D.S. Korzhinskiy and V.A. Nikolayev, Associate Member of the U.S.S.R. Academy of Sciences. The high honor was conferred upon these scientists for their participation in the joint work, "Fundamental Problems in the Study of Ore Deposits of Magmatic Origin".

It is well known that the development of the theory of endogenic ore formation has involved great difficulties, since the processes that have formed magmatic ore deposits, both in the past and in the present time, take place in the deeper parts of the earth's crust, which are inaccessible to direct observation. It was therefore inevitable that the widely known theory of magmatic ore formation set forth in Lindgren's works should, with the gradual increase in geologic knowledge, come to be in opposition to the actual facts and to be subjected to criticisms and corrections, especially on the part of Soviet geologists.

Thus a great need has arisen for the establishment of a new theory of the formation of ore deposits that would correspond to the present level of development of geologic science. This exceedingly important task was begun in 1947 by the late Academician S.S. Smirnov and carried on after his death: the first edition of "Fundamental Problems in the Study of Ore Deposits of Magmatic Origin" was published in 1953, but a second edition of this book was already required in 1955.

The materials for which this high honor was awarded -- the articles by A.G. Betekhtin, A.N. Zavaritskiy, D.S. Korzhinskiy and V.A. Nikolayev in this symposium -- throw a newer and greater light on many problems of ore formation associated with magmatic activity; they represent an enormous contribution to the knowledge of ore deposits, and thus also to the scientific basis of exploring, prospecting and evaluating ore deposits in the endeavor to expand the raw material resources of industry.

The huge amounts of factual data compiled by the many Soviet geologists and contained in their works have been condensed into a series of new and original theoretical formulations that have a strict basis in the physico-chemical sciences, but are nevertheless closely tied to the practical work of mining and ore prospecting.

A.G. Betekhtin, in four papers -- 1) "Hydrothermal Solutions, their Nature and the Processes of Ore Formation," 2) "The Processes of Ore Formation in Hydrothermal Vein Deposits," 3) "The Causes of the Movement of Hydrothermal Solutions" and 4) "The Genetic Connection between Hydrothermal Formations and Intrusive Bodies" -- has presented a detailed analysis of a number of very complicated questions: the processes of formation and deposition of ores and the migration of hydrothermal solutions; the mechanism by which deposits are formed; the sources of the metallic compounds accumulated in these deposits and their genetic association with intrusive rocks of various compositions; the sulfur and oxygen regimes, the behavior of the hydrocarbons, and the roles played by water, alkalis and acids in the processes of migration and redeposition of mineral substances; the role played by liquid inclusions; the paragenetic mineral associations, colloidal and metacolloidal formations and the metamorphism of ores; the causes of the movement of hydrothermal solutions, from the standpoint of hydrodynamics and hydrogeology; the mechanisms involved in the formation of various types of deposits; the classification of hydrothermal deposits according to their association with various types of igneous rocks; etc.

The enormous amount of extremely varied factual material upon which these articles are based, the critical analysis of the views existing up to the present, their verification from the standpoint of the exact sciences (mineralogy, physical chemistry, hydraulics, etc.) and the practical aspects of mining and mineral prospecting -- all these are included in the methods used by the author in his papers.

A.G. Betekhtin's conclusions present a picture of all the stages in the process of endogenic ore formation, from the moment the elements are segregated from the magma to the formation and alteration of the deposits under various conditions of interaction with the host rocks, until they are brought to the earth's surface.

D.S. Korzhinskiy's "Outlines of Metasomatic Processes" is a summation of the

author's previous investigations in this field. The processes associated with alterations around the borders of the ore bodies are here examined in the light of broad theoretical conclusions drawn from numerous concrete examples. The article describes the processes of metasomatism during the magmatic and post-magmatic stages, and presents a detailed analysis of bimetasomatism and contact-infiltration metasomatism and of the processes and types of skarn formation.

The short article by A.N. Zavaritskiy "On Pegmatites as Formations Intermediate between Igneous Rocks and Ore Veins" first appeared in 1944, but has retained its importance up to the present time as an introduction to the understanding of magmatogenic ore formation.

V.A. Nikolayev's article on "The Problem of the Genesis, the Hydrothermal Solutions and the Stages of Magmatic Processes Occurring at Depth" presents the author's studies of the peculiar features of the crystallization of binary and ternary silicate systems with volatile components, as applied to the investigation of magmatic processes taking place at depth and to the physico-chemical aspects of the formation of natural hydrothermal solutions.

A.G. Betekhtin, A.N. Zavaritskiy, D.S. Korzhinskiy and V.A. Nikolayev have, of course, clarified and more precisely elaborated a number of aspects, but have not yet produced a final solution to the problem of magmatogenic ore formation. They are continuing their theoretical investigations in this field.

Thus, for example, Academician A.G. Betekhtin has presented the results of his further study of the laws governing the processes of ore deposition in a number of chapters of a new jointly authored book, "Ore Textures and Structures", which has appeared in print. Academician D.S. Korzhinskiy in 1957 published his paper on "The Physico-chemical Basis for the Analysis of Mineral Paragenesis".

There is no doubt that these winners of the Lenin Prize will produce more works on the theory of ore forming processes. It is hoped that they will enjoy continuing success in this endeavor, which is so important for the economy of this country and the welfare of its people.

D.I. Shcherbakov

ACADEMICIAN N.S. SHATSKIY,  
WINNER OF THE LENIN PRIZE  
IN 1958

The scientific community has joyfully welcomed the award of the Lenin Prize in 1958 to the editor of the tectonic map of the U.S.S.R. and the adjoining countries, on the scale of 1:5,000,000. This map, which is a synthesis of the collective work of a whole army of Soviet geologists, represents a great forward step in the scientific knowledge of nature. The guiding spirit, the organizer, the director and the main executor of this project was Academician Nikolay Sergeyevich Shatskiy.

The first synthesis of the tectonic structure of the U.S.S.R. was made twenty-five years ago by A.D. Arkhangel'skiy and N.S. Shatskiy. The construction of this tectonic map in 1933, which deservedly attracted the attention of the world's geologic community, was based on historical principles -- the age of the completed folded structures in the individual major geologic regions of the country. The great amounts of new information recently accumulated by Soviet geologists and geophysicists and the systematic study of the tectonics of the U.S.S.R. enabled N.S. Shatskiy, at the head of an organization of his colleagues in the Geological Institute of the U.S.S.R. Academy of Sciences, to publish, in 1952, the first tectonic map of the U.S.S.R. on the scale of 1:4,000,000, which has become widely known in the Soviet Union. This first tectonic map of the U.S.S.R. was distinguished from the tectonic maps of the United States of America (1944, 1951) and Canada (1950), which were constructed according to formal principles and did not sufficiently reveal the historical development of the North American continent.

Under the direction of Academician N.S. Shatskiy, a new tectonic map of the U.S.S.R. and the adjoining countries, on a scale of 1:5,000,000, was prepared for the Twentieth International Geological Congress held in Mexico in 1956. This map was universally approved, and its editor, director and chief executor, Academician N.S. Shatskiy, was awarded the Lenin Prize in 1958. The new tectonic map was worked out in greater detail than its earlier version. In compiling this map, not only the latest published works but also a large quantity of unpublished material from various organizations was used. The map distinguishes tectonic structures of various orders, as well as intrusives of various ages and compositions, from the historical standpoint.

The tectonic map of the U.S.S.R. and adjoining countries clearly reflects the high level of geologic science in the U.S.S.R.

the rapidity with which it has grown. The geologic history of the territory of the U.S.S.R., as expressed on the tectonic map, inevitably leads to a critical reconsideration of M. Bertrand's and E. Zeuss's classic ideas of the coincidence in time and place of the periods of folding and the individual phases in this process. The map shows the following periods of folding: Cambrian, Proterozoic, Baykal or Reef, Caledonian, Hercynian (Variscian), Mesozoic and two Cenozoic -- the Alpine and the Circum-Pacific Ocean belt.

The Baykal period of folding (at the end of the Proterozoic and beginning of the Cambrian), which was distinguished by N.S. Shatskiy, is of the same order of importance as the Caledonian, Hercynian and Alpine periods that were first noted by E. Zeuss and M. Bertrand.

A study of the new tectonic map of the U.S.S.R. and the materials on which it is based will also lead to a number of other important conclusions: such as a reduction of the post-geosynclinal stages of the Caledonian cycle, in contrast to the Hercynian, in which the final stages in the development of the folded zones were exceedingly long; the origin and growth of border synclinal structures are associated with these terminal stages. The map also clearly reflects the enormous importance and independent position of the Mesozoic period of folding, which has been well known to Soviet geologists for a long time. Many facts, moreover, have confirmed the existence of two regions of Mesozoic folding occurring at different times -- that of the Alpine period of folding and a younger one, the Circum-Pacific belt, in which the folding is still far from completion. Analysis of the tectonic map of the U.S.S.R. and adjoining countries also clearly suggests the very important idea that there has been a sharp division through-

out geologic history between the Pacific Ocean belt on the one hand and Europe and the western parts of Asia on the other. The new tectonic map supports Academician V.I. Vernadskiy's concept of a "disymmetry" in the development of this planet.

The tectonic map of the U.S.S.R. will serve as the basis for further investigation of many problems in theoretical tectonics; beyond this, however, this map is already of practical importance as a possible basis for the construction of metallogenic maps and maps for forecasting the location of various mineral deposits.

The new tectonic map of the U.S.S.R., as Academician D.I. Shcherbakov has pointed out, attracted the attention of geologists from all over the world who participated in the Twentieth International Geological Congress. It has become an important teaching aid in numerous schools of higher education in Western Europe (England, Belgium, France and other countries). The London Geological Society at the end of the past year devoted a special session to the tectonic map of the U.S.S.R. S.N. Bubnov and other prominent scientists of other countries have highly praised the new tectonic map of the U.S.S.R., which became familiar to thousands who viewed the Soviet pavilion at the Brussels International Exposition.

Under these circumstances, it was quite natural that Academician N.S. Shatskiy at the recent International Tectonic Congress in Paris should have been elected President of the International Commission for constructing a tectonic map of Europe. It is sincerely hoped that Academician Nikolay Sergeevich Shatskiy, winner of the Lenin Prize, will enjoy new success in his efforts toward the development of Soviet and world science.

Ye. V. Pavlovskiy

## REVIEWS AND DISCUSSIONS

### "THE PETROGRAPHY OF IGNEOUS ROCKS", by BOHUSLAV HEJTMAN<sup>1</sup>

by V. P. Petrov

The two books which make up this text were published independently of each other in 1956 and 1957 by the Academy of Sciences of Czechoslovakia; both have been approved by the Ministry of Schools and Cultures as textbooks for institutions of higher education.

These two books are quite unusual, since they are based on a large amount of original Czech material. Inasmuch as they reflect the petrographic interests of Czech specialists, they are also of primary interest to Soviet petrographers and geologists. Unfortunately, they also contain a number of statements that must be considered as somewhat unfortunate.

The first book, "The General Petrography of Igneous Rocks", which was issued in 1956 as a volume of 369 pages, contains both indexes and a long bibliography showing extensive use of works in Russian. As its title indicates, this volume presents an analysis of the general aspects of petrography. It begins with a general introduction and a review of the methods used in petrography, pointing out the particular importance of microscopic methods of investigating rocks. It should be mentioned that at the very beginning Prof. B. Hejtman analyzes quantitative microscopic calculations from thin sections, pointing out that there are two basic methods of performing such calculations -- the linear and the Glagolev point method. The great attention that he devotes to quantitative mineralogical methods is quite proper, in view of the importance of the quantitative mineral composition of rocks in petrography; it is thus a cause for regret that the quantitative mineral composition is scarcely considered later on, although it would have been useful in describing the rocks of Czechoslovakia

that are discussed in the second book.

The following section deals with the distribution of the various rocks in nature, including both a general sketch of the distribution of the different types of rocks and data on Czechoslovakia as a whole and on its most varied tectonic structures -- the Czech massif and the Carpathian mountain structures (see Fig. 1). The differences between them are very clear and specific: metamorphic and igneous rocks predominate in the Czech massif, whereas in the Carpathians they are of secondary importance.

Later sections of the text are devoted to the geochemical aspects of the structure of the silicates and to the classification of rocks; the author attaches particularly great importance to this problem and presents a detailed analysis of Johanssen's mineralogical classification, Trager and Shand's classification, the chemical computations and classifications made by F. Yu. Levinson-Lessing, Ozann, Niggli, Wolf and A. N. Zavaritskiy, and the Cross-Iddings-Pirsson and Washington methods. To facilitate these computations, mathematical tables from Osann are given at the end of the book.

In spite of the great importance attached to the methods of computation, almost no use of these methods is made later on in the text; instead, the data from the chemical analyses are presented directly. This, of course, is quite proper, since the original figures characterize the composition of the rocks much more accurately than any recomputation of them.

B. Hejtman bases his classification of rocks on his own original mineralogical classification, in which he distinguishes three main types on the vertical line: rocks containing quartz, rocks containing neither quartz nor feldspathoids, and feldspathoid rocks. Within each of these three types he distinguishes intrusive, dike and extrusive rocks. Along the horizontal line on the Table, the rocks are divided according to the content and amount of feldspars of the content of feldspathoids (see Table 1). In spite of the great originality of this classification and its many very interesting aspects (such as the subdivision of the alkali

<sup>1</sup>Hejtman, Bohuslav. 1) Vseobesna petrografie vyvrelých hornin, 1956. 2) Systematica petrografie vyvrelých hornin, 1957. Nakladatelství Československé akademie věd, Praha.

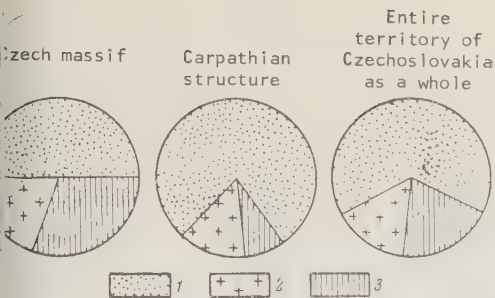


Fig. 1. The distribution of the main rock types in Czechoslovakia and its individual parts, according to B. Hejtman.

1 -- sedimentary rocks; 2 -- igneous rocks; 3 -- metamorphic rocks.

extrusives and the detailed subdivision of the granitoids), it also contains some important defects. The chief of these, in the reviewer's opinion, is that the author fails to consider cenotypal and paleotypal extrusives. Such a distinction would tie the petrographic classification more closely to the general scheme of geologic chronology and in many cases would bring out the geologic peculiarities of one district or another. The English school of petrographers also ignores this distinction. B. Hejtman, however, who is very well acquainted with the Russian and German literature, clearly sees all the advantages of separating these two groups, and throughout the succeeding text (especially in the second book) he stresses the paleotypal or cenotypal nature of the rocks. This distinction should also have been made in the classification, the more so because the classification lists parallel terms for rocks. There is little point in making further use of the very poor English term "rhyolite" to designate any acidic, light-colored, extrusive rock, since the term "liparite" is much more specific in this respect. The position of monzonite in B. Hejtman's classification is also hard to understand; it can hardly be considered as a variety of syenite. It is more usual to make the term "monzonite" as a synonym for gabbro-syenite or, in extreme cases, for syenite-diorite.

There is also little advantage in distinguishing a special series of dike rocks, especially since such proper dike rocks as aplite, odinite, lamprophyre, bostonite and many others are not listed in the Table. It would have been more correct to call this class of rocks porphyritic (hypabyssal), since granite-porphyr, syenite porphyry and others often form fairly large massifs,

whereas spilites and diabases also form dikes.

In discussing the distribution of rocks according to their compositions, B. Hejtman cites Richardson's and Snisbee's statistical curve, which of course is very indicative; in the reviewer's opinion, however, it would have been interesting to supplement these with P.N. Kropotkin's curve, which shows very clearly that the two peaks on Richardson's distribution curve are due to the specially great concentration of acidic rocks among intrusives and of basic rocks among extrusives.

Further chapters discuss the nature of the rock-forming minerals and the crystallization of artificial melts, with an analysis of very excellent examples of the zones of plagioclases. There is an explanation of the conditions under which magma crystallizes, including the temperature, viscosity (making much use of M.P. Volarovich's data) and state of the magma in the depths of the earth; all this is done with extensive use of material from the literature and of original Czechoslovakian data, especially in the section on rock-forming minerals. This part of the book will make very interesting reading for the Soviet reader, since it provides a summary of the minerals occurring in Czechoslovakia. B. Hejtman unfortunately pays little attention to the optical constants of the minerals he describes; this will probably be a serious defect for the Czechoslovakian students who use this book.

In contrast to many other similar textbooks, this book also devotes some attention to the physical properties of rocks: specific gravity, temporary resistance to crushing, changes in orientation, color, the extent to which they can be polished, etc.

The book ends with chapters analyzing the laws governing the associations of rocks and their genesis. The latter chapter is, unfortunately, too short. There is a great variety among present-day theories of the origins of rocks, so that the specialist needs more extensive information in order to find his way clearly in the literature on the subject. Each specialist must base his personal judgement of these theories on investigations made for this purpose in the field; these can be carried only by knowing the fundamental principles of these theories and the facts on which they are based.

The contents of the second book, published in 1957 as "The Systematic Petrography of Igneous Rocks", are fully indicated by the title. In a short introduction the author presents the above-mentioned table, showing his suggested classification of rocks.

Table 1. B. Hejtman's Classification of Igneous Rocks

	A	B	C	D	E	F	G	H				
I. With Quartz	alkaline	Plag. Alk. Plagioclase	Plag. Alk. Plagioclase more acid than No. 50	Plagioclase more acid than No. 50	Plag. Alk. More basic than No. 50	Plagioclase more basic than No. 50	Plagioclase more basic than No. 50	Without luminous minerals	a - intrusive, b - dike, c - extrusive rocks. Rocks saturated and oversaturated with silica above heavy line; undersatur- ated rocks below. The letters of the Czech alphabet have been used to designate the rock classes, as was done by B. Hejtman.			
	a	alkalic granite	granodiorite	quartz diorite	grano- gabbro	quartz gabbro						
	b	alkalic granite porphyry	granodiorite porphyry	quartz diorite porphyry		quartz gabbro porphyrite						
II. Without Quartz or Felspathoids	c	quartz keratophyre, pantellerite, comendite	rhyo-dacite	quartz porphyrite, dacite	rhyo-basalt	quartz diabase, basalt						
	a	alkalic syenite	syenite- diorite (monzonite)	diorite	syenite- gabbro	gabbro (anorthosite)	olivine gabbro	peridotite				
	b	alkalic syenite porphyry	syenite- diorite porphyry	diorite porphyry, kersantite, spessartite		gabbroic porphyrite	(camptonite monchiquite)					
III. With Felspathoids	c	keratophyres alkaline trachyte	trachy- andesite	porphyrite, andesite	trachy- basalt	spilite, diabase, melaphyre, basalt	olivine diabase, melaphyre, olivine basalt					
	a	felspathoid syenite	rongstokite	felspathoid diorite	essexite	theralite		picrite	CH with nepheline	J with leucite	K with sodalite	L with melilitite,
	b	nepheline- syenite porphyry			essexite porphyrite	camptonites and monchiquites ( with felspathoids)			urtite, iolite	fergusite, missourite	tawite	turyite uncompah- grite
c	phonolite	phonolite- tephrite nepheline latite	felspathoid trachy- andesite	felspathoid andesite	felspathoid trachy- basalt	tephrite (augitite)	basanite (limburgite)		ijolite porphyry		tawite porphyry	alnite, polzenite
								nephe- linites, olivine nephelinites	leucite, olivine leucitite		sodalite, noseanite, haüynite	melilitite, olivine melilitite

The remaining 360 pages are devoted to descriptions of the individual rock types in the order in which they occur in the classification table (IA - the alkalic granite group, IB - the granite group, etc., down to III - the carbonatite group).

In spite of the author's strictly formal approach to the classification of rocks into groups, the essence of his description of these rocks is not at all formal. Wherever possible, he uses original Czechoslovakian materials, finally presenting an interesting petrographic summary of the rocks of Czechoslovakia. Each description and analysis of a rock, which is often taken from the older literature, is tied to one locality or another; geologic maps are given of the most typical areas in which certain of the rocks occur. There is some especially interesting material on the Krkonoše-Guerskiy and the Carlsbad massifs, the Erzgebirge and the group of phonolite massifs in the areas of Ust' on the Laba ("Ausig in Bohemia") and around Bilin and Most and on a number of other localities. Only for those groups of rocks on which there are no actual Czechoslovakian data does the author use materials from other countries, making great use of Soviet literature, as before. The various rock groups are very unequally treated: a large amount of space is devoted to those which are most widespread in Czechoslovakia, whereas only brief accounts are given of the rocks that do not occur in that country.

The Soviet reader will find this book particularly interesting. The rocks of Bohemia and Slovakia were described earlier in numerous Viennese and German works, in which it was sometimes extremely difficult to find any petrographic data on these rocks. B. Hejtman has gathered this information together, and his "systematic petrography" will serve as an excellent guide to the rocks of Czechoslovakia, especially since it includes a well prepared index and a list of German names and of Czech and Slovak geographic terms.

The formal petrographic approach to the arrangement of the material in the text conflicts sharply with the general geologic nature of the exposition. The author is forced to return repeatedly to areas already mentioned earlier in the book, and some of the most important aspects involved in the interrelationships between the rocks, the variations in their composition and the problems of their origin are thus left out of the descriptions of various districts.

The book reviewed here will quite obviously arouse great interest both in Czechoslovakia and in other countries, particu-

larly in the Soviet Union, and a new edition will be required very soon. This reviewer suggests that the author divide his book into two parts: a "systematic petrography" proper which presents only the petrographic characteristics in describing the rocks, and a "regional petrography of Czechoslovakia", containing a full exposition of the geologic position of the igneous rocks and of the importance of igneous activity in the geologic history of the territory of Czechoslovakia.

Both books, as already mentioned, are supplied with long bibliographies, which greatly enhance their value. The first book lists 403 titles, of which 17 percent are by Russian, 15 percent by Czech and 2 percent by Polish and Bulgarian authors. Of the 494 titles listed in the second book, 52 percent are Czech, 7 percent Russian, 5 percent Polish, Bulgarian and Yugoslavian and only the remaining 36 percent are written in Western European languages. The literature in Czech, which before the Second World War was scarcely available to Soviet specialists, is scantily treated in bibliographies and foreign reference journals, so that there have been many obstacles to its use. B. Hejtman's bibliographies will do much to further the use of Czechoslovakian literature.

The list of Czech and Slovak place names juxtaposed with their old Germanized versions, by which they were known in the literature before 1917, will be of great use to the reader.

These two books deal only with the petrography of igneous rocks; the problems of metamorphism both in the depths of the earth's crust and under the conditions close to the surface, where many minerals are formed, still remain to be treated. The author evidently proposes to take up these questions, which are of more pressing importance at the present time, in his succeeding works. The originality of his approach to the igneous rocks leads one to expect similarly interesting and original works from the author in this field as well.

SOME REMARKS ON D.O. ONTOYEV'S ARTICLE "ON THE CONDITIONS GOVERNING THE LOCALIZATION OF NICKEL-COBALT ARSENIDE ORES IN THE CARBONATE VEINS WITHIN SKARN ROCKS"

by N.N. Shishkin

The "Bulletin of the Academy of Sciences of the USSR, Geologic Series", No. 9, 1957 contained an article by D.O. Ontoyev "On the Conditions Governing the Localization of

Nickel-cobalt Arsenide Ores in Carbonate Veins within Skarn Rocks". The arsenic-nickel-cobalt deposit of Khovakhsa in the Tuva Autonomous Oblast', about which the author is writing in his article, has been studied by a large number of geologists since its discovery by V.A. Unksov, G.N. Ivanova, A.A. Bogomol and V.A. Bobrov. Besides the above-mentioned persons, investigations of the geology of the region and the deposit have been made by V.I. Bondarenko, S.N. Kondakov, Ye.G. Starostina, R.S. Tarasova and N.A. Tikhomirova, and of the mineralogy of the deposit by V.A. Unksov, and Ye.I. Nefedov (VSEGEI), M.G. Markina, A.Ya. Volzhenskova, A.P. Polushkina (VIMS), N.N. Shishkin, A.Ye. Aleshunina, V.A. Mikhaylova (Gipronikel'), G.A. Krutov, L.K. Yakhontova, A.A. Godovikov (MGU) and L.I. Gavrilova (Uralmekhanoobr). The results of these studies are contained in numerous reports and in many published articles [1-6].

Thus the appearance of a new article on this deposit cannot fail to arouse the reader's interest.

Unfortunately, D.O. Ontoyev has not studied the papers by a large number of investigators of this deposit, and has set forth a number of facts inaccurately and sometimes even incorrectly.

One case in point is the association of the ore formation with skarn rocks. The results of investigations made in recent years by V.A. Unksov and the author of these observations show that not all of the replaced rocks, as was thought earlier, are properly called skarns. The rocks which are not skarn include the low-iron prehnite, prehnite-scapolite and scapolite rocks occurring mainly throughout the sandstones and siltstones -- rocks with a clay cement.

Later on, the author of the article says that "as the veins move downward in depth from the skarns into the sandstones and granites, and also upward (and in places along the strike) in the argillites, the content of industrially valuable nickel-cobalt ores drops sharply and the veins actually become barren, although they are composed of the same carbonate minerals" (p. 50). This statement, which is correct in principle, requires clarification. In recent years [3] underground workings in individual veins have encountered lenses of rich ores in the siltstones (argillites, according to D.O. Ontoyev), which lie above the level of the skarn rocks.

Dwelling very briefly on the mineral composition of the veins, D.O. Ontoyev in-

cludes ankerite among the chief vein minerals, although the content of this mineral [3] in the veins of the deposit is negligible. Among the main ore minerals of the veins he lists skutterudite, though its distribution is very limited, and in the oxide zone he includes arsenolite and scorodite -- minerals which also have a very limited occurrence in this deposit. On the other hand, smolyanovite [5, 6], which is well known in the deposit, is not even mentioned.

Farther on, the author writes that the metasomatic carbonate rock consists mainly of fine-grained ankerite. Studies under the microscope, chemical analyses and X-ray investigations, however, show that this rock is made up of dolomite and calcite, whereas the ankerite in it occurs very infrequently and appears along the border with the granite.

The data from chemical analyses of 16 samples of mineralized metasomatic carbonate rocks show that the average content of FeO is 2.06 percent (ranging from 0 to 5.35 percent), while that of MgO is 6.92 percent, CaO is 27.3 percent and CO<sub>2</sub> is 22.45 percent. Thus not ankeritization, as the author asserts, but dolomitization is the main process involved in the formation of the metasomatic carbonate rocks which contain the arsenide-carbonate (chiefly arsenide-calcite) veins [3].

The author ought to have based his judgments on a thorough study of the mineral content of both the host rocks and the ore veins and paragenetically associated minerals, taking account of the results obtained by the above-mentioned investigators.

## REFERENCES

1. Glazkovskiy, A.A. INSTRUKTSIYA PO PRIMENENIYU KLASSIFIKATSII ZAPASOV K MESTOROZHDENIYAM KOBALTOPYKH RUD [INSTRUCTIONS ON APPLYING THE PRINCIPLES OF CLASSIFICATION TO DEPOSITS OF COBALT ORES]: Gosgeoltekhizdat, 1956.
2. Mokiyeviskiy, V.A., NAUCHNAYA SESSIYA FYEDOROVSKOGO INSTITUTA SOVMESTNO SO VSESOUZNYM MINERALOGICHESKIM OBSHCHESTVOM [JOINT SCIENTIFIC SESSION OF THE FYEDOROVSKIY INSTITUTE AND THE ALL-UNION MINERALOGICAL SOCIETY]: Zapiski Vses. Mineralog. O-va, Ch. 82, Vyp. 4, 1953.
3. Shishkin, N.N. and V.A. Mikhaylova,

IZUCHENIYE VESHCHESTVENNOGO  
SOSTAVA RUD KHOVAKHSINSKOGO  
KOBALT'OGO MESTOROZHDENIYA  
[A STUDY OF THE COMPOSITION OF  
THE ORES IN THE KHOVAKHSINSKIY  
COBALT DEPOSIT]: Sb. 6 Tekhn. In-  
form. In-ta Gipronikel', 1956.

Yakhontova, L.K. and G.A. Sidorenko,  
O NOVOM MINERALE -- ARSENAT-  
BELOVITE [THE NEW MINERAL --  
ARSENATE-BELOVITE]: Zapiski Vses.  
Mineralog. O-va, Ch. 85, Vya. 3,  
1956.

Yakhontova, L.K., NOVYY MINERAL --  
SMOL'YANOVIT [A NEW MINERAL --  
SMOLYANOVITE]: Doklady, Akademiya  
Nauk SSSR, t. 109, No. 4, 1956.

, NOVYY MINERAL --  
SMOL'YANOVIT [A NEW MINERAL --  
SMOLYANOVITE]: Trudy Mosk.  
Geol.-Razved. In-ta, t. 29, 1956.

ON A.G. ALIYEV AND V.P. AKAYEVA'S  
BOOK, "THE PETROGRAPHY OF THE  
JURASSIC DEPOSITS IN THE SOUTH-  
EASTERN CAUCASUS"<sup>1</sup>

by G.N. Brovkov

The Jurassic deposits form a very large and important part of the complex of sedimentary rocks in the Caucasus. It is sufficient to say that their greatest total thickness within the southeastern Caucasus exceeds 10,000 meters, and that numerous mineral deposits are associated with them: coal, siderite, limestone, dolomite, gypsum and anhydrite, sulfur, celestite, gas and oil occurrences, etc. It is natural, therefore, that in recent years an ever greater number of geologists should have made detailed studies of the lithology of the Jurassic deposits, and that the book under consideration here, which is a compilation of data on the Jurassic petrography and mineralogy of the southeastern Caucasus, should serve as a good basis for similar investigations.

The authors have set themselves the task of studying in detail the material composition of the rocks in the southeastern Caucasus, their facies peculiarities and the paleogeographic conditions under which they were accumulated, to distinguish those which correspond petrographically and stratigraphically, and on this basis to correlate the stratigraphic sections of this region. More

than 5,000 different analyses were made, and 19 sections are described.

After a brief review of the stratigraphy based mainly on the literature, chapters I and III, which present the petrographic features of the predominant rock types and sections, form the main part of the book (more than 75 percent of its length). Here the general features of the terrigenous, argillaceous and carbonate rocks -- their granulometric composition, their texture and structure, their cement and their mineral composition -- are considered in detail, concretions are described, some questions of mineral formation are touched on and a petrographic analysis of the sections through the Jurassic strata is made. The text is well illustrated with numerous tables and figures.

Some remarks must be made on the contents of these two chapters. It is impossible, for example, to agree with the classification of the cross bedded series (types of bedding) presented by the authors. Four types of series (those with concave and concavo-convex beds leveling off at the base; those with a supposed alternation between gray and reddish-brown parallel beds; cross bedded series; and those with thin slantwise and wavy beds) have been distinguished on the basis of different criteria: in one case the scale of the series, in another the form of the bedding and the color of the rocks, and in still another the relationships with the neighboring series.

The morphological classification, in the reviewer's opinion, should have been based on two or three criteria used in conjunction (the scale of the series, their interrelationship and the form of the bedding), and this principle should have been maintained from the beginning to the end. These four types of series, moreover, are at the same time considered as four types of bedding, and their genetic interpretation is often erroneous. The first type of bedding the authors consider to be mainly deltaic-littoral-marine (? - G.B.), although, to judge from the illustrations and the description, it is usually encountered in channel and partly in deltaic deposits. The third type of bedding, which the authors call littoral-marine, is also more typical of delta and channel deposits, and is not considered by the majority of lithologists to be an independent type. The term "curve-bedded" is hardly a good one.

A.G. Aliyev and V.P. Akayeva have oversimplified the classification of the carbonate rocks. Crystalline and pelitomorphic limestones cannot properly be considered as independent types, if the petrographic com-

<sup>1</sup>Press of the Azerbaidjan SSR Academy of Sciences, Baku, 1957.

position is the basis of the classification; the degree of crystallization is a structural criterion of limestones.

The authors, on the basis of chemical analyses, follow S.G. Vishnyakov in dividing carbonate rocks into such types as sub-sandy, sandy and dolomitized sandy limestones, marls and clay marls. But an almost negligible amount of silicon dioxide in the limestones is not always a reason for calling them sandy (silicified limestones). This classification makes no mention of merely dolomitized limestones and dolomites, which occur in the deposits of the Upper Jurassic.

Some inaccuracies have crept into the microscopic description of the limestones: cryptocrystalline and petitic structures have been indicated in the case of bioclastic limestones (p. 117), and in characterizing the sandy limestones mention is made of the structure of the cement, for which there is no basis, etc.

The description of the concretions omits one essential aspect -- the relationship between their composition and the facies of the containing rocks. The main problems of authigenic mineral formation in the Jurassic rocks of the southeastern Caucasus are given scant treatment.

In a short chapter IV, "The petrographic criteria for the stratigraphic correlation of the Jurassic deposits in the southeastern Caucasus", the authors have attempted to describe the petrographic and mineralogical characteristics of the suites distinguished by previous investigators. This attempt, unfortunately, is based on a single section (that of the Babachay River), so that the conclusions cannot be extended to the whole of the southeastern Caucasus because of the rapid facies changes in the Jurassic deposits.

The terrigenous-mineralogical provinces established by A.G. Aliyev and V.P. Akayeva (in chapter V) are fairly well founded, although it must be said that there is little basis for extending the terrigenous-mineralogical provinces to the territory of Dagestan, where only individual sections scores of kilometers distant from each other have been studied.

The concluding chapters VI and VII analyze the facies and the paleogeographic conditions under which the Jurassic deposits were accumulated. Within these strata the authors have found only marine facies, which they subdivide into shoreline, shallow-water and deep-water types. Brief petrographic descriptions, diagrammatic maps and block diagrams of the facies are given. The paleogeographic aspects (the location of

the sources of material in the deposits, the means and the conditions of transportation, the climate, etc.) are thoroughly discussed and well argued, taking full account of the work done by previous investigators (V.Ye. Khain, N.N. Rostovtsev, I.A. Konyukhov and others).

Some observations must also be made on the chapter devoted to the facies of the deposits. There is no basis for the author's categorical statement that there are only marine facies in the Jurassic deposits of the southeastern Caucasus. According to observations made by the reviewer, southwestern Dagestan contains undoubted continental deposits which include not only coals (mentioned in passing in the paleogeographic outline on p. 200), but also channel, flood-plain and lacustrine deposits. The facies in the Jurassic complex are much more varied than the present work would indicate. Familiarity with the sections through the Jurassic in the parts of Dagestan next to Azerbaydzhan would show that there are no less than 13 or 14 facies here, and that they cannot in any way be encompassed by the three facies described in this monograph: littoral, shallow-water and deep-water. Such an approach would require grouping argillites, silt and sandstones, conglomerates and pelitomorphous limestones in a single shallow-water facies (see pp. 188 - 189), which can hardly be considered correct. Continental deposits, including coal, are grouped within the shoreline facies of the Aalenian stage (see pp. 186 - 187). The authors contradict themselves, when they constantly speak of a shallow-water facies and in the same context of shallow-water facies (shoreline and others also): a facies and a group of facies are not the same thing.

The above-mentioned classification of facies is also reflected in the facies maps, which are little different from the usual very schematic petrographic sketch maps.

A.G. Aliyev and V.P. Akayeva have, in a number of cases, allowed some inaccuracies to remain in their section on the use of authigenic minerals as criteria of the geochemical conditions. In the case of the shallow- and moderately deep-water deposits of the Toarcian stage (see pp. 186 and 199 - 200), for example, they assume that oxidizing conditions predominated in the formation of the sediments, on the basis of the presence of iron hydroxides, iron-clay (?) lenses and nodular interbeds (which?) in the rocks. This is not convincing, since the iron hydroxides in the Toarcian rocks, which are usually dark-colored and rich in carbonized plant detritus, as a rule appear only in the weathered zone as ferrous iron compounds. In another case

p. 201), the authors, finding considerable quantities of limonite, pyrite, siderite and iron-carbonate concretions in the Aalenian rocks, conclude that there might have been hydrogen sulfide contamination in the basin; it is hard to concur in this without being sure of the secondary nature of the iron hydroxides, and it is more logical to assume that there was only temporary hydrogen sulfide poisoning in the mud and not in the water of the basin. In order to solve such problems, one must pay strict attention to the time of formation of the authigenic minerals and their associations, and not confuse the water in the mud with the water above the mud level.

The absence of a section in the monograph devoted to even a brief description of the ore deposits associated with the Jurassic sedimentary complex must be considered a defect.

In conclusion, the reviewer wishes to say that, in spite of some defects, the monograph by A.G. Aliyev and V.P. Akayeva on "The Petrography of the Jurassic Deposits in the Southeastern Caucasus" is a broadly inclusive and very useful work that will be read with interest by many geologists. There is no doubt that geologists in the Caucasus will make use of it in their scientific and practical work.

## BIBLIOGRAPHY

LITERATURE ON GEOLOGY  
AND RELATED SCIENCES  
RECEIVED BY THE LIBRARY OF THE  
DEPARTMENT OF GEOLOGICAL AND  
GEOGRAPHIC SCIENCES OF THE  
ACADEMY OF SCIENCES  
OF THE U.S.S.R.  
IN JUNE 1958

### A. Articles in Periodicals

#### GEOLOGY

1. Abdulin, A.A., K GEOLOGII TURMALINOVO-MEDNOGO RUDOPROYAVLENIYA SARYMSAK (TSENTRALNYY KAZAKHSTAN) [THE GEOLOGY OF THE TOURMALINE-COPPER ORE DEVELOPMENT IN SARYMSAK (CENTRAL KAZAKHSTAN)]: Vestn., Akademiya Nauk KazSSR, no. 4.
2. Avilov, I.K., NOVAYA TEKSTURA MORSKIKH OSADKOV [A NEW STRUCTURE OF MARINE SEDIMENTS]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
3. Azizbekov, Sh. A. and M.I. Rustamov, O NIZHNEPLIOTSENOVOM EFFUZIVNOM VULKANIZME NAKHICHEVANSKOY SKLADCHATOY OBLASTI [THE LOWER PLIOCENE EFFUSIVE VULCANISM IN THE NAKHICHYEVAN FOLDED REGION]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 4.
4. Aleksin, A.A., OB UGLENOSNOSTI TRE-TICHNYKH OTLOZHENIY SREDNEGO TECHENIYA R. OBI [THE COALS OF THE TERTIARY DEPOSITS ALONG THE MIDDLE COURSE OF THE OB' RIVER]: Vestn., Zap.-Sib. Geol. Upr., no. 2, 1957.
5. Alizade, A.A., et al., K TEKTONIKE KARADAGA [THE TECTONICS OF KARADAG]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 1.
6. Anisimov, V.R., CHETVORTICHNOYE OLEDENENIYE KHREBTA EZOP [QUATERNARY GLACIATION OF THE EZOP RANGE]: Sov. Geol., no. 4.
7. Afonichev, N.A., O SILURIYSKIKH OTLOZHENIYAKH NA SEVERNOM SKLONE DZHUNGARSKOGO ALATAU [SILURIAN DEPOSITS ON THE NORTHERN SLOPE OF DZHUNGARSKIY ALATAU]: Sov. Geol., no. 4.
8. Akhmedbeyli, F.S., NEKOTORYYE PRIMERY MELKOY SKLADCHATOSTI ADZHINOURA (ZAPADNYY AZERBAYDZHAN) [A FEW EXAMPLES OF OPEN FOLDING IN ADZHINOUR (WESTERN AZERBAYDZHAN)]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 5.
9. Balukhovskiy, N.F., PRIRODA (TEORIYA) GEOLOGICHESKOY TSIKLIČNOSTI [THE NATURE (THEORY) OF GEOLOGICAL CYCLES]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, no. 2.
10. Baranov, V.I. and L.A. Kuz'mina, SKOROST' OTLOZHENIYA ILOV INDIYSKOGO OKEANA [THE RATE OF SEDIMENTARY DEPOSITION IN THE INDIAN OCEAN]: Geokhimiya, no. 2.
11. Baranov, I. Ya., NEKOTORYYE ZAKONOMERNOSTI RAZVITIYA TOLSHCH MNOGOLETNEMERZLYKH GORNYKH POROD I SEZONNOGO PROMERZANIYA POCHVY [CERTAIN RULES IN THE DEVELOPMENT OF PERMANENTLY FROZEN ROCKS AND THE SEASONAL FREEZING OF THE SOIL]: Izv., Akademiya Nauk SSSR, Ser. Geogr., no. 2.
12. Bashkirov, L.V., ORBITOIDY I IKH ZNACHENIYE DLYA STRATIGRAFIY PALEOGENA [THE ORBITOIDS AND THEIR SIGNIFICANCE IN PALEOGENE STRATIGRAPHY]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
13. Bel'skaya, T.N., PALEOGEOGRAFIYA KUZNETSKOY KOTLOVINY V POZDNE DEVONSKUYU EPOKHU [PALEO GEOGRAPHY OF THE KUZNETS SYNCLINE DURING THE LATE DEVONIAN EPOCH]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
14. Bobruv, Yu. P., K VOPROSU IZUCHEN-

## BIBLIOGRAPHY

- IYA TEKTONICHESKOGO RAZVITIYA STRUKTURY SARATOVSKOGO PRAVO-BEREZH'YA [STUDY OF THE TECTONIC DEVELOPMENT IN THE STRUCTURE OF THE SARATOV RIGHT BANK]: Geol. Nefti, no. 5.
- Bogdanov, N.A., SKHEMY STRATIGRAFI DOKEMBRIYSKIKH OTLOZHENIY KHREBTOV DZHAGDY I TUKURINGRA [STRATIGRAPHIC DIAGRAMS OF THE PRECAMBRIAN DEPOSITS IN THE DZHAGDA AND TUKURINGRA RANGES]: Sov. Geol., no. 4.
- Bogdanov, A.A., O GEOLOGII LANGE-DOKA I VOSTOCHNYKH PIRENEYEV [THE GEOLOGY OF LANGUEDOC AND THE EASTERN PYRENEES]: Byul., MOIP, Otd. Geol., t. 33, vyp. 2.
- Bondarchuk, V.D., GEOLOGICHNI SPOSTEREZHENIYA V ISPANII [GEOLOGICAL INVESTIGATIONS IN SPAIN]: Visn., Akademiya Nauk URSS, no. 4.
- Budag, Budagov, O NOVEYSHIKH TEKTONICHESKIKH DVIZENIYAKH YUGO-VOSTOCHNOGO KAVKAZA [THE MOST RECENT TECTONIC MOVEMENTS IN THE SOUTHEASTERN CAUCASUS]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 5.
- Vaidov, V.M. and I.M. Konovalov, O TEKTONICHESKOM OBOSOBLENII TALYSHA [THE TECTONIC ISOLATION OF TALYSH]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 3.
- Vdovin, V.V., SOVREMENNIYE STRUKTURY MEZOKAYNOZOYSKOGO POKROVA POLYARNY ZONY ZAPADNO-SIBIRSKOY NIZMENNOSTI [CONTEMPORARY STRUCTURES OF THE MIDDLE-CENOZOIC MANTLE IN THE POLAR ZONE OF THE WESTERN SIBERIAN PLAIN]: Izv. Siber. Otd., Akademiya Nauk SSSR, no. 3.
- Vistelius, A.B., SKHEMA RAYONIROVANIYA ALLYUVIALNYKH OTLOZHENIY PAMIRA PO IKH MINERALNYM ASSOCIATSIYAM [DIAGRAM OF THE DISTRIBUTION OF ALLUVIAL DEPOSITS IN THE PAMIRS ACCORDING TO THEIR MINERAL ASSOCIATIONS]: Doklady, Akademiya Nauk, t. 118, no. 6.
- Vikhert, A.V., O TEKTONIKE ZAPADNO-VERKHNOYANSKOGO ANTIKLINORIYA [THE TECTONICS OF THE WESTERN VERKHNOYANSK ANTICLINORIUM]: Izv. Sib. Otd., Akademiya Nauk SSSR, no. 3.
23. Vishnevskaya, I.I., M.I. Kudryavtsev, and I.F. Trusova, NOVYYE DANNYYE PO GEOLOGII DOKEMBRIYSKIKH OBRATZOVANIY ATASUYSKOGO RAYONA (TSENTRAL'NYY KAZAKHSTAN) [NEW DATA ON THE GEOLOGY OF THE PRECAMBRIAN FORMATIONS OF THE ATASUYSKIY REGION (CENTRAL KAZAKHSTAN)]: Izv. Vyssh. Ucheb. Zaved., Ser. Geol. i Razv., no. 2.
24. Gevasimova, Ye. T., K FATSIALNO-LITOLOGICHESKOY KHARAKTERISTIKE SREDNEFRANSKIKH OTLOZHEMY VOSTOKA TATARII I PRILEGAYUSHCHIKH TERRITORIY [THE FACIES -- LITHOLOGIC CHARACTERISTICS OF THE MIDDLE FRANSIAN DEPOSITS OF EASTERN TATAR AND ADJOINING TERRITORIES]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
25. Gerenchuk, K.I., O TIPAKH SOOTNOSHENIY SOVREMENNOY OROGRAFIYI RUSSKOY RAVNINY S TEKTONICHESKIMI STRUKTURAMI PLATFORMY [TYPES OF CONTEMPORARY RELATIONSHIPS BETWEEN THE OROGRAPHY OF THE RUSSIAN PLAIN AND THE TECTONIC STRUCTURES OF THE PLATFORM]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
26. Gzovskiy, M.V., METOD MODELIROVANIYA V TECTONOFIZIKE [METHODS OF MAKING MODELS IN TECTONIC PHYSICS]: Sov. Geol., no. 4.
27. Godin, Yu. N., KOMPLEKSNIYE REGIONAL'NIYE GEOFIZICHESKIYE ISSLEDOVANIYA YUGO-VOSTOKA RUSSKOY PLATFORMY [COMPLEX REGIONAL GEOPHYSICAL INVESTIGATIONS OF THE SOUTHEASTERN RUSSIAN PLATFORM]: Geol. nefti, no. 5.
28. Gorelova, S.G., O STRATIGRAFIYI RASPADSKOGO MESTOROZHDENIYA KUZ-BASSA [STRATIGRAPHY OF THE RASPADSKIY DEPOSITS OF THE KUZ-BAS]: Vestn., Zap.-Sib. Geol. Upr., Vyp. 2, 1957.
29. Goretsky, G.I., BURTASSKOYE SREDNEANTROPOGENOVYE OZERO I PROBLEMA KOLEBANIYA UROVNYA MIROVOGO OKEANA V SVYAZI S OLEDENENIEM [THE BURTASS MIDDLE ANTHROPOGENE LAKE, AND THE PROBLEM OF FLUCTUATIONS IN THE LEVEL OF THE

- WORLD'S OCEANS ASSOCIATED WITH GLACIATION]: Byul., MOIP, Otd. Geol. t. 33, Vyp. 2.
30. Gorzhevsky, D.I. and G.F. Yakovlev, PROYAVLENIYE TEL'BESSKOY FAZY TEKTOGENEZA NA RUDNOM ALTAYE [EVIDENCE OF THE TELBESS STAGE OF TECTOGENESIS IN RUDNYY ALTAY]: Sov. Geol., no. 4.
  31. Gurulev, S.A., O KRATNOSTI CHET-VERTICHNOGO OLEDENENIYA V BARGUZINSKOM KHREBTE [THE RECURRENCE OF QUATERNARY GLACIATION IN THE BARGUZINSKIY RANGE]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
  32. Daminova, A.M., MAGMATICESKIYE FORMATSII TSENTRAL'NOGO TAYMYRA [THE MAGMATIC FORMATIONS OF THE CENTRAL TAYMIR]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  33. Dembo, G.M., O GEOLOGICHESKOY KLASSIFIKATSII YAVLENIY METAMORFIZMA [THE GEOLOGICAL CLASSIFICATION OF METAMORPHIC PHENOMENA]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  34. Dovgal', V.N., GEOLOGIYA DEVONSKOGO MAGMATICESKOGO KOMPLEKSA RAYONA ABAKANSKOVO ZHELEZORUDNOGO MESTOROZH-DENIYA [GEOLOGY OF THE DEVONIAN MAGMATIC COMPLEX IN THE AREA OF THE ABAKAN IRON DEPOSITS]: Izv. Sib. Otd., Akademiya Nauk SSSR, no. 3.
  35. Dolgova, V.N., LITERATURA PO GEOLOGII UKRAINY ZA 1955 G [LITERATURE ON THE GEOLOGY OF THE UKRAINE FOR 1955]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
  36. Doroshko, S.M., O VERKHNEDEVONSKIKH OTLOZHENIYAKH SHARYPOVSKOGO RAYONA KRASNOYARSKOGO KRAYA [THE UPPER DEVONIAN DEPOSITS OF THE SHARYPORSKIY REGION OF KRASNOYARSKIY KRAY]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
  37. Yentsova, F.I., K VOPROSU O PARAGENEZISE UGLENOSNOSTI I KONKRETSIYENOSNOSTI [THE PROBLEM OF THE PARAGENESIS OF COAL AND CONCRETIONS]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
  38. Yefimtsev, N.A., DREVNEYE OLEDENIYE ZAPADNOY TUVY [ANCIENT GLACIATION OF WESTERN TUVA]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  39. Zhamoyda, A.I., N.S. Podgornaya, and M.I. Sosnina, O NIZHNEKAMENNOVGOL'NYKH OTLOZHENIYAKH SIKHOTE-ALINY (BASSEYN R. AVVAKUMOVKI) [THE LOWER CARBONIFEROUS DEPOSITS OF SIKHOTE-ALIN (AVVAKUMOVKA RIVER BASIN)]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
  40. Zhukov, G.V., O NOVOM RAYONE RAZVITIYA ZHELEZISTO-KREMNIISTYKH FORMATSII NA UKRAINE [A NEW REGION OF DEVELOPMENT OF IRON SILICA FORMATIONS IN THE UKRAINE]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
  41. Il'in, A.V., STRATIGRAFIYA DOKEMBRIYSKIKH OTLOZHENIY ZAPADNOY CHASTI NAGOR'YA SANGILEN (TUYA) [THE STRATIGRAPHY OF THE PRE-CAMBRIAN DEPOSITS OF THE WESTERN PART OF THE SANGILEN HIGHLANDS (TUYA)]: Sov. Geol., no. 4.
  42. Ismaylov, K.A. and M.N. Radzhabov, GEOLOGICHESKIYE USLOVIYA ZALEGANIYA VERKHNEMELOVYKH IZVESTNYAKOV V PREDELAKH ASTARINSKOGO ANTIKLINORIYA (TALYSHCHSKIYE GORY) [GEOLOGICAL CONDITIONS OF DEPOSITION OF THE UPPER CRETACEOUS LIMESTONES IN THE ASTARIN ANTICLINORIUM (TALYSHINSKIYE MTS.)]: Doklady, Akademiya AzSSR, t. 14, no. 4.
  43. Ismet, R.A., ZNACHENIYE VOPROSA OPREDELENIYA GLUBINY PLASTA PO OSI SKVAZHINY DLYA RESHCHE-NIYA RYADA GEOLOGICHESKIKH ZADACH [THE IMPORTANCE OF THE PROBLEM OF DETERMINING THE DEPTH OF THE AXIS OF A DRILL HOLE TO SOLVE GEOLOGICAL PROBLEMS]: Izv. Vyssh. Ucheb. Zaved., Ser. Neft' i Gaz, no. 1.
  44. Kapitsa, A.P., DINAMIKA LEDNIKOVOGO POKROVA ANTARKTIDY V RAYONE RABOT KOMPLEKSNYOY ANTARTICHESKOY EKSPEDITSII AN SSSR [DYNAMICS OF THE ANTARCTIC ICE SHEET IN THE AREA COVERED BY THE JOINT ANTARCTICA EXPEDITION OF THE ACADEMY OF SCIENCES OF THE USSR]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  45. Karlov, N.N., OB OBSHCHEY ZAKO-

- NOMERNOSTI IZMENENIYA MOSHCH-NOSTI I GRANULOMETRICHESKOGO SOSTAVA PRIDNEPROVSKOVO LESSA [GENERAL REGULARITY OF CHANGES IN THE THICKNESS AND GRANULARITY OF THE DNEPR LOESS]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
- Kizeval'ter, D.S., et al., NOVYYE DANNYYE O VOZRASTE KAMMENDUGOL'NOY TOLSHCHI V TSENTRAL'NOY CHASTI SEVERNOGO KAVKAZA [NEW DATA ON THE AGE OF THE CARBONIFEROUS FORMATIONS IN THE CENTRAL PART OF THE NORTHERN CAUCASUS]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
- Kirillov, I.V., GIPOTEZA RAZVITIYA ZEMLI, YEYE MATERIKOV I OKEANICHESKIKH VPADIN [HYPOTHESIS FOR THE DEVELOPMENT OF THE EARTH, ITS CONTINENTS AND OCEANIC TROUGHS]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
- Konyukhov, I.A., Yu. K. Burlin, and A.M. Seregin, NIZHNEMELOVYYE OTLOZHENIYA SEVERNOGO KAVKAZA I IKH LITOLOGO-FATSIAL'NYYE IZMENENIYA [LOWER CRETACEOUS DEPOSITS OF THE NORTHERN CAUCASUS AND CHANGES IN THEIR LITHOLOGY AND FACIES]: Geol. Nefti, no. 4.
- Koronovskiy, N.V. and Ye. Ye. Milanovskiy, STROYENIYE I ISTORIYA FORMIROVANIYA VULKANA EL'BRUS [THE STRUCTURE AND HISTORY OF THE DEVELOPMENT OF THE ELBRUS VOLCANO]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
- Kravchinskiy, Z. Ya., GEOTERMICHE-SKIYE USTOVIYA POLUOSTROVA CHELEKEN [GEOTHERMAL CONDITIONS ON THE CHELEKEN PENINSULA]: Izv., Akademiya Nauk TurkmSSR, no. 2.
- Krayerskaya, L.N., K VOPROSU O RASPROSTRANENII VERKHNEDEVON-SKIKH OTLOZHENIY NA SEVERE KUZBASSA [THE DISTRIBUTION OF UPPER DEVONIAN DEPOSITS IN THE NORTHERN KUZBAS]: Vestn. Zap. - Sib. Geol. Upr., Vyp. 2, 1957.
- Krandiyevskiy, V.S., K VOPROSU O STRATIGRAFIY VERKHNE-LUDLOV-SKIKH OTLOZHENIY PODOLII (NA OSNOVANII IZUCHENIYA OSTRAKOD) [THE STRATIGRAPHY OF THE UPPER LUDLOVIAN DEPOSITS OF PODOLE (ON THE BASIS OF OSTRACOD STUDIES)]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
53. Krasil'nikov, B.N. and A.A. Mossakovskiy, SKLADKI OBLEKANIYA SEVERNOY CHASTI MINUSINSKOY KOTLOVINY I IKH SVYAZ' S KALEDON-SKIMI STRUKTURAMI [THE STRATA SUPERIMPOSED ON THE UNCONFORMITY DEVELOPED ON FOLDED STRUCTURES IN THE NORTHERN PART OF THE MINUSINSK BASIN, AND THEIR RELATION TO CALEDONIAN STRUCTURES]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
54. Kurshs, V.M., SUSHCHESTRUYET LI USINSKAYA ANTIKLINAL'NAYA STRUKTURA [ON THE EXISTENCE OF THE USINSK ANTICLINAL STRUCTURE]: Vest. Zap. -Sib. Geol. Upr., Vyp. 2., 1957.
55. Liverzon, I.M., NEKOTORYYE CHERTI SKLADCHATYKH STRUKTUR DASH-KESANSKOGO RUDNOGO RAYONA [SOME CHARACTERISTICS OF THE FOLDED STRUCTURES IN THE DASH-KESAN MINING REGION]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 5.
56. Lisitsyn, A.P. and A.V. Zhivago, REL'YEF DNA I OSADKI YUZHNOY CHASTI INDIYSKOGO OKEANA [RELIEF OF THE OCEAN FLOOR AND THE SEDIMENTS IN THE SOUTHERN PART OF THE INDIAN OCEAN]: Izv., Akademiya Nauk SSSR, Ser. Geogr., no. 2.
57. Loginova, V.N., LITOLOGIYA SARGA-YEVSKIKH OTLOZHENIY VOSTOKA TATARSKOY ASSR [LITHOLOGY OF THE SARGAYEV FORMATIONS OF THE EASTERN TATAR ASSR]: FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
58. Makerenko, D. Ye., PERESMOTR STRATIGRAFICHESKOGO POLOZHENIYA LATTORFSKOGO YARUSA GERMANII [A REVIEW OF THE STRATIGRAPHIC SITUATION OF THE LATTORFSKIAN STAGE IN GERMANY]: Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
59. Mamlin, N.S. and L.D. Staroverov, ITOGI GEOLOGICHESKIKH RABOT V ZAPADNOY SIBIRI K 40-LETIYU OKTYABR'SKOY REVOLYUTSII [RESULTS OF GEOLOGICAL WORK IN WESTERN SIBERIA ON THE FORTIETH ANNIVERSARY OF THE OCTOBER REVOLUTION]: Vestn. Zap. - Sib. Geol. Upr., Vyp. 2, 1957.

60. Matviyenko, E.M., O METODIKE KOM-  
PLEKSNOMY GEOLIGICHESKOY  
SYEMKI SLABOBNASHCHENNYKH I  
ZAKRYTYKH RAYONOV PLATFOR-  
MENNOY CHASTI UKRAINSKOY SSR  
[METHODS OF COMPLEX GEOLOGI-  
CAL SURVEYS IN POORLY EXPOSED  
OR COMPLETELY CONCEALED AREAS  
OF THE UKRAINIAN PLATFORM]:  
Geol. Zhurn., Akademiya Nauk UkrSSR,  
t. 18, Vyp. 2.
61. Meshcheryakov, Yu. A., NOVYYE  
MATERIALY PO GEOMORFOLOGII I  
NEOTEKTONIKE BASHKIRSKOY ASSR  
[NEW DATA ON THE GEOMORPHOL-  
OGY AND RECENT TECTONICS OF  
THE BASHKIR ASSR]: Izv., Akademiya  
Nauk SSSR, Ser. Geogr., no. 2.
62. Miropol'skaya, G.L., O PRERYVISTOSTI  
OSADKONAKOPLENIIYA V TERRIGEN-  
NOY TOLSHCHE DEVONA NA VOS-  
TOKE TATARII [DISCONTINUITY OF  
DEPOSITION IN THE DEVONIAN CON-  
TINENTAL SERIES OF EASTERN  
TARTAR]: Izv. Kazansk. FAN SSSR,  
Ser. Geol. Nauk, no. 6, 1957.
63. Miropol'skiy, L.M., O PROYAVLENI-  
YAKH MAGMATIZMA V KAMSKO-  
VOLZHSKOM KRAYE [THE DEVEL-  
OPMENT OF MAGMATISM IN THE  
KAMA-VOLGA DISTRICT]: Izv.  
Kazansk. FAN SSSR, Ser. Geol. Nauk,  
no. 6, 1957.
64. V.I. Radziyevskiy, NEKROLOG [OBITU-  
ARY]: Geol. Zhurn., Akademiya Nauk  
UkrSSR, t. 18, Vyp. 2.
65. Miroshnikov, L.D., DOMELOVYYE  
SBROSY V UST'-YENISEYSKOM RAY-  
ONE [PRE-CRETACEOUS FAULTS IN  
THE UST'-YENISEY REGION]: Geol.  
Nefti, no. 4.
66. Moldavskiy, B.S., O GEOLOGICHES-  
KIKH FAKTORAKH TZMENENIYA  
PLOTNOSTI OSADOCHNYKH POROD  
AZERBAYDZHANA [THE GEOLOGICAL  
FACTORS INFLUENCING THE CHANGE  
IN DENSITY OF SEDIMENTARY  
ROCKS]: Izv. Vyssh. Ucheb. Zaved.,  
Ser. Neft i Gaz, no. 3.
67. Mustafayev, I.S., K LITOLOGO-FAT-  
SIAL'NYM OSOBENNOSTYAM OTLO-  
ZHENIY PRODUKTIVNOY TOLSHCHI  
SEVERO-ZAPADNOY CHASTI APSHER-  
ONSKOGO POLUOSTROVA [THE  
LITHOLOGIC-FACIES CHARACTERIS-  
TICS OF THE DEPOSITS OF THE  
PRODUCING SERIES OF THE NORTH-  
WESTERN PART OF THE APSHERON  
PENINSULA]: Izv. Vyssh. Uchebn.  
Zaved., Ser. Neft' i Gaz, no. 3.
68. Nadirov, S.G. and M.M. Zeynalov,  
NOVOYE IZVERZHENIYE GRYAZE-  
VOGO VULCANA BOZDAG (KOBIYSKIY)  
[NEW ERUPTIONS OF THE MUD VOL-  
CANO, BOZDAG (KOBIYSKIY)]: Az.  
neft. khoz., no. 3 (381).
69. Nevolin, N.V., OSNOVNYE CHERTI  
STROYENIYA FUNDAMENTA TSEN-  
TRAL'NYKH I VOSTOCHNYKH I GEO-  
GRAFICHESKIM DANNYM [BASIC  
FEATURES OF THE BASEMENT ROCK  
OF THE CENTRAL AND EASTERN  
REGIONS OF THE RUSSIAN PLAT-  
FORM FROM GEOLOGICAL AND  
GEOGRAPHICAL DATA]: Doklady, Ak-  
ademiya Nauk SSSR, t. 119, no. 3.
70. Neyshadt, M.I., V SOVETSKOY SEKTSII  
MEZHDUNARODNOY ASSOTSIIATSII PO  
IZUCHENIYU CHETVERTICHNOVO  
PERIODA [THE SOVIET SECTION OF  
THE INTERNATIONAL ASSOCIATION  
FOR THE INVESTIGATION OF THE  
QUATERNARY PERIOD]: Izv., Akad-  
emiya Nauk SSSR, Ser. Geogr., no.
71. Nikolayev, V.A., K ISTORII VOSTOCH-  
NOGO MANYCHA V CHETVERTICH-  
NOYE VREMYA [THE HISTORY OF  
EASTERN MANYCH IN THE QUATE-  
RNARY PERIOD]: Izv. Akademiya Nauk  
SSSR, Ser. Geogr., no. 2.
72. O DEYATEL'NOSTI GEOLOGICHESKIKH  
SEKTSIY MOSKOVSKOGO OBSHCHEST-  
VNOGO SOYUZA [THE ACTIVITIES  
OF THE MOSCOW SOCIETY FOR  
NATURE STUDY]: Byul., MOIP, Otd.  
Geol., t. 33, Vyp. 2.
73. Ovnanatov, S.T. and G.P. Tamrazyan,  
GEOLOGICHESKIYE OSOBENNOSTI  
ZALEGANIYA KALINSKOY SVITY V  
BINA-GOUSANSKOY MUL'DE APSHER-  
ONSKOGO POLUOSTROVA I NEKO-  
TORYE VOPROSY NAPRAVLENIYA  
POISKOVYKH RABOT NA NEFT' I  
GAZ KaC [GEOLOGICAL CHARAC-  
TERISTICS OF SEDIMENTATION IN  
THE KALINSKIY FORMATION OF THE  
BINA-GOUSANSKY TROUGH ON THE  
APSHERON PENINSULA, AND TRENDS  
IN OIL AND GAS PROSPECTING]: Az.  
Neft. Khoz. no. 3 (381).
74. Palant, I.B., STRATIGRAFICHESKOYE  
SOPOSTAVLENIYE RAZREZOV VER-  
KHNE PERMSKIKH KRASNOTSvet-  
NYKH OTLOZHENIY PO OSTRAKODAM  
[STRATIGRAPHIC CORRELATION OF  
UPPER PERMIAN CROSS-SECTIONS  
OF THE OSTRACOD RED-BED FOR-

# BIBLIOGRAPHY

- mations]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
75. Pergament, M. A., STRATIGRAFIYA APT-AL'BSKIKH I VERKHNEMELOVYKH OTLOZHENIY SEVERO-ZAPADNOY KAMCHATKI [STRATIGRAPHY OF THE APTIAN-ALBIAN AND UPPER CRETACEOUS DEPOSITS OF NORTH-WESTERN KAMCHATKA]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
76. Petrenko, A. A. and A. Ye. Mogilev, O STRUKTURNO-TEKTONICHESKIKH OSOBENNOSTYAKH YEGORSHINSKOY UGLENOSNOY POLOSYY NA URAL'E [THE STRUCTURAL AND TECTONIC CHARACTERISTICS OF THE YEGORSHINSK COAL BELT IN THE URALS]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
77. Puchkov, S. V., et al., NOVOYE SIL'-NOYE ZEMLETRYASENIYE V VOSTOCHNOY SIBIRI [RECENT INTENSE EARTHQUAKES IN EASTERN SIBERIA]: Izv. Sib. Otd. Akademiya Nauk SSSR, no. 3.
78. Raznitsyn, V. A., O GRANITSE DEVONA I KARBONA NA YUZHNOY TIMANE [EXTENT OF THE DEVONIAN AND CARBONIFEROUS IN SOUTHERN TIMAN]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
79. Rantsman, Ye. Ya., K VOPROSU O NESOVPADENII ALPIYSKIKH I NEO-TEKTONICHESKIKH STRUKTUR V ZAALAYSKOM KHREBTE [VARIATION IN THE ALPIAN AND RECENT TECTONIC STRUCTURES OF THE TRANSALAY RANGE]: Izv., Akademiya Nauk SSSR, Ser. Geogr., no. 2.
80. Rengarten, P. A., GERTSINSKIYE STRUKTURNO-FATSIAL'NYE ZONY VOSTOCHNOGO PRIBALKHASH'YA [HERCYNIAN STRUCTURAL-FACIES ZONES IN THE EASTERN BALKASH AREA]: Sov. Geol., no. 4.
81. Siroshstan, R. I. and M. I. Chernovskiy, SOPOSTAVLENIYE POROD SREDNEY SVITY LIKHMANOVSKOY SINKLINALI TARAPAKO-LIKHMANOVSKOY ANTIKLINALI V KRIVBASSE [A COMPARISON OF THE ROCKS FROM THE MIDDLE FORMATIONS OF THE LIKHMANOVSKIY SYNCLINE, AND THE TARAPAK-LIKHMANOVSKIY ANTI-CLINE IN THE KRIVBAS]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
82. Slavin, V. I. and V. Ya. Dobrynina, STRATIGRAFIYA YURSKIKH OTLOZHENIY L'VOVSKOY MULDY I PRED-KARPAJSKOGO KRAYEVOGO PROGIBA [STRATIGRAPHY OF THE JURASSIC DEPOSITS OF THE L'VOV TROUGH, AND THE PRE-CARPATHIAN AREA FLEXURE]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
83. Solov'yeva, M. N., and V. D., Chekhovich, OCHERK STRATIGRAFIY I GEOLOGICHESKOGO STROYENIYA GORY MERISHKOR (KHREBET NURA-TAU) [OUTLINE OF THE STRATIGRAPHY AND GEOLOGICAL STRUCTURE OF MERISHKOR MT. (NURA-TAU RANGE)]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
84. Sysoyev, N. N., G. B. Udintsev and I. B. Andreyeva, REZULTATY SEYSMOAKUSTICHESKIKH ISSLEDOVANIY DNA YAPONSKOGO MORYA [RESULTS OF SEISMIC INVESTIGATIONS IN THE JAPANESE SEA]: DAN SSSR, vol. 119, no. 3.
85. Tikhomirov, V. G., CHERTY UNASLEDOVANNOSTI V RAZVITII PALEOZOY-SKIKH STRUKTUR SARYSU-TENGIZ-SKOGO PODNYATIYA (TSENTRAL'NOY KAZAKHSTAN) [INHERITED FEATURES IN THE DEVELOPMENT OF THE PALEOZOIC STRUCTURES OF THE SARYSU-TENGIZ UPLAND (CENTRAL KAZAKHSTAN)]: Sov. Geol., no. 4.
86. Tikhomirova, Ye. S., K VOPROSU OB USLOVIYAKH NAKOPLENIYA OTLOZHENIY YASNOPOLYANSKOGO PODYARUSA YUGO-ZAPADNOY CHASTI PODMOSKOVNOGO BASSEYNA [DEPOSITIONAL CONDITIONS OF THE YASNOPOLYANSK SUB-STAGE IN THE SOUTHWESTERN PART OF THE MOSCOW BASIN]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
87. \_\_\_\_\_, NOVYYE DANNYE O STROYENII UPINSKIKH OTLOZHENIY V PODMOSKOVNOM BASSEYNE [NEW DATA ON THE STRUCTURE OF THE UPINSK DEPOSITS IN THE MOSCOW BASIN]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
88. Khain, V. Ye., SOVREMENNYE GEOTEKTONICHESKIYE GIPOTEZY (OPYT KRITICHESKOGO ANALIZA) [CONTEMPORARY GEOTECTONIC HYPOTHESES (ANY EXPERIMENT IN CRITICAL ANALYSIS)]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
89. Chernysheva, Z. S., NOVYYE DANNYE

- K OPREDELENIYU VOZRASTA SYR-TOVYKH GLIN ZAVOLZH'YA [NEW DATA ON THE AGE DETERMINATION OF THE BOG CLAYS IN THE TRANS-VOLGA AREA]: Izv., Akademiya Nauk SSSR, Ser. Geogr., no. 2.
90. Chernyshevskaya, Z. A. and M. F. Filipova, NOVYYE DANNYYE O STRATIGRAFII VERKHNEGO DEVONA TATARSKOY ASSR [NEW DATA ON THE UPPER DEVONIAN STRATIGRAPHY OF THE TARTAR ASSR]: Geol. Nefti, no. 4.
  91. Chumakov, N. M., NOVYYE DANNYYE O GEOLOGICHESKOM STROYENII YUGO-ZAPADNOGO OBRAMLENIYA VILYUYSKOY VPADINY [NEW DATA ON THE GEOLOGICAL STRUCTURE OF THE SOUTHWEST MARGIN OF THE VILYUY DEPRESSION]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 3.
  92. Shikhalibeyli, E. Sh., NEKOTORYYE OSOBNOSTI ISTORII RAZVITIYA REL'YEFA TSENTRAL'NOY CHASTI MALOGO KAVKAZA V PREDELA KH AZERBAYDZHANA [CERTAIN FEATURES ABOUT THE DEVELOPMENT OF THE RELIEF IN THE CENTRAL PART OF THE LESSER CAUCASUS IN THE AZERBAJDAN SECTOR]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 4.
  93. Eberzin, A. G., SKHEMA STRATIGRAFII MORSKIKH NEOGENOVYKH OTLOZHENIY ZAKASPIYA [STRATIGRAPHIC SECTION OF THE MARINE NEOGENE DEPOSITS IN THE TRANS-CASPIAN AREA]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  94. Yakovlev, S. A., NEKROLOG [OBITUARY]: Sov. Geol., no. 4.
- PALEONTOLOGY
95. Bagmanov, M. A., NOVYYE DANNYYE O GEOGRAFICHESKOM RASPROSTRANENII PODRODA SEMIVERTAGUS COSSMANN [NEW DATA ON THE GEOGRAPHIC DISTRIBUTION OF THE SUBGENUS SEMIVERTAGUS COSSMANN]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 3.
  96. Gabuniya, L. K., O CHEREPE ROGATOY ISKOPAYEMOY SVIN'YI IZ SREDNEGO MIOTSENA KAVKAZA [THE SKULL OF A FOSSIL PIG FROM THE MIDDLE MIOCENE OF THE CAUCASUS]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
  97. Grigor'yev, V. N., NOVAYA NAKHODKA FAUNY NA SEVERA-ZAPADE SIBIRSKOY PLATFORMY I RASCHLENENIYE NIZHNEGO KEMBRIYA IGARSKOGO RAYONA [A NEW FAUNA DISCOVERY IN THE NORTHWESTERN SIBERIAN PLATFORM AND AN ANALYSIS OF THE LOWER CAMBRIAN OF THE IGARKA REGION]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
  98. Karavayev, M. N., ISKOPAYEMYYE KHOVONYYE TRETICHNOGO I CHETVERTICHNOGO PERIODOV V BASSEYNE R. LENY [FOSSIL CONIFERS OF THE TERTIARY AND QUATERNARY PERIODS IN THE LENA RIVER BASIN]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  99. Kulinyeva, Kh. M., O MIKROFAUNE APSHERONSKOGO YARUSA YUGO-ZAPADNOVO TURKMENISTANA [THE MICROFAUNA OF THE APSHERON FORMATION OF SOUTHWEST TURKMEN S.S.R.]: Izv., Akademiya Nauk TurkmSSR, no. 2.
  100. Merklin, R. L., O GIDROLOGII I GIDROBIOLOGII GEL'VETSKOGO MORYA NA YUGE SSSR (PO DANNYM EKOLOGII MOLLYUSKOV) [THE HYDROLOGY AND HYDROBIOLOGY OF THE HELVETIAN SEA IN SOUTHERN U.S.S.R. (ACCORDING TO ECOLOGICAL DATA ON MOLLUSCS)]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
  101. Miklukho-Maklay, A. D. and I. M. Ruskov, KOMPLEKSY FORAMINIFER PALEOZOYA KORYAKSKOGO KHREBTA [PALEOZOIC FORAMINIFERA COMPLEXES OF THE KORYAK RANGE]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
  102. Pogrebnyak, V. O., NEKOTORYYE NOVYYE VIDY FUZULINID IZ SREDNEKAMENNOUGOLNYKH OTLOZHENIY SEVERNOY OKRAINY DONETSKOGO BASSEYNA [NEW TYPES OF FUSULINIDS FROM THE MIDDLE CARBONIFEROUS DEPOSITS ON THE NORTHERN EDGE OF THE DONETS BASIN]: Geol. Zhurn., Akademiya Nauk USSR, t. 18, Vyp. 2.
  103. Savel'yev, A. A., LONGINUCULANA KRUTSCHININI SAVEL GEN. ET. SP. NOV. IZ VERKHNEAPTISKIKH OTLOZHENIY MANGYSHLAKA [LONGINUCULANA KRUTSCHININI SAVEL GEN. ET. SP. NOV. FROM THE UPPER

## BIBLIOGRAPHY

- APTIAN DEPOSITS OF MANGYSHLAK]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
04. Stepanayts, N. Ye., NOVYYE VIDY OSTRAKOD IZ OTLOZHENIY BAKIN-SKOGO YARUSA ZAPADNOY TURKMENII [NEW TYPES OF OSTRACODS FROM THE BAKINIAN FORMATION DEPOSITS OF WESTERN TURKMENIA]: Izv., Akademiya Nauk TurkmSSR, no. 2.
- PETROGRAPHY, MINERALOGY,  
CRYSTALLOGRAPHY, GEOCHEMISTRY
05. Abdullayev, R.N., OB ABSOLYUTNOM VOZRASTE NEKOTORYKH INTRUZIVNYKH OBRAZOVANII MALOGO KAVKAZA [THE ABSOLUTE AGE OF CERTAIN INTRUSIVES IN THE LESSER CAUCASUS]: Doklady, Akademiya AzSSR, t. 14, no. 3.
06. Alekin, O.A. and N.P. Moricheva, VLIYANIYE KARBONATNOY SISTEMY V PRIRODNYKH VODAKH NA SODERZHANIYE ORGANICHESKIKH VESHCHESTV [EFFECT OF A CARBONATE SYSTEM IN VADOSE WATERS ON ORGANIC MATTER CONTENT]: Doklady, Akademiya Nauk SSSR, t. 119, no. 2.
07. Ananyan, A.A., PRIMENENIYE KINETICHESKIKH PREDSTAVITELEY, RAZVITYKH DLYA VODNYKH RASTVOROV ELEKTROLITOV V VADE SODERZHASHCHIKHSYN V GORNYKH PORODAKH [THE ADAPTATION OF KINETIC REPRESENTATIONS DEVELOPED FOR WATER SOLUTIONS OF ELECTROLYTES TO THE WATER CONTAINED IN ROCKS]: Byul, MOIP, Otd. Geol., t. 33, Vyp. 2.
08. Afanas'yev, G.D., PIS'MO V REDAKTSIYU [LETTER TO THE EDITORS]: Geokhimiya, no. 2.
09. Baranov, V.I., MEZHDUNARODNAYA KONFERENTSIYA PO PRIMENENIYU RADIOIZOTOPOV V NAUCHNYKH ISSLEDOVANIYAKH [INTERNATIONAL CONFERENCE ON THE USE OF RADIOISOTOPES IN SCIENTIFIC RESEARCH]: Geokhimiya, no. 2.
10. Borovik-Romanova, T.F. and Ye. D., Kalita, O TSEZIEVO-RUBIDIEVOM MIKROKLIN-PERTITE I RASPROSTRANENII V NEM REDKIKH SHCHELOCHNYKH METALLOV [THE CESIUM-RUBIDIUM MICROELINE-PERTHITES, AND THE OCCURRENCE OF RARE ALKALINE METALS WITH THEM]: Geokhimiya, no. 2.
111. Burkser, Ye. S., F.I. Kotlovskaya, and B.B. Zaydis, OPYT OPREDELENIYA ABSOLYUTNOGO VOZRASTA NEKOTORYKH KAMENNYKH METEORITOV PRI ISPOL'ZOVANII OSAZHDENIYA KALIYA TETRAFENILBORIDOM NATRIYA [AN EXPERIMENT TO DETERMINE THE ABSOLUTE AGE OF CERTAIN METEORITES BY PRECIPITATING CALCIUM FROM SODIUM TETRAPHENYLBORIDE]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
112. Velichko, Ye. A., K PETROGRAFI PERMSKOGO TERRIGENNOGO KOMPLEKSA V RAYONE TAYMYRSKOGO OZERA [PETROGRAPHY OF THE PERMIAN CONTINENTAL COMPLEX IN THE TAYMYR LAKE REGION]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
113. Vendel'shteyn, B. Yu., K VOPROSU O PRIRODE DIFFUZIONNO-ADSORBTSIONNYKH POTENTIALOV GORNYKH POROD [THE NATURE OF THE DIFFUSION-ADSORPTION POTENTIALS OF ROCKS]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 1.
114. Volkova, I.B., PETROGRAFICHESKIY SOSTAV I USL OVIYA OBRAZOVANIYA UGLEY NIZHNEMEZOZOYSKIKH MESTOROZHDENIY KAZAKHSTANA [THE PETROGRAPHIC COMPOSITION AND MESOZOIC COAL DEPOSITS IN KAZAKHSTAN]: Doklady, Akademiya Nauk SSSR, t. 119, no. 2.
115. Vyalov, O.S. and V.S. Sobolev, GORA GAUSS V ANTARKTIKE [GAUSS MOUNTAIN IN THE ANTARCTIC]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
116. Vyalov, O.S. and L.G. Tkachuk, IZVESTNYAKOVYYE KOROKHI S OKRAIN POSELKA MIRNYY V ANTARKTIDE [LIMESTONE CRUSTS FROM THE AREAS AROUND MIRNYY STATION IN THE ANTARCTIC]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
117. Gavrilova, L.K. and N.V. Turanskaya, RASPREDELENIYE REDKIKH ZEMEL' V PORODO-OBRAZUYUSHCHIKH I AKTSESSORNYKH MINEVALAKH NEKOTORYKH GRANITOV [THE DISTRIBUTION OF RARE EARTHS IN REEF FORMATIONS AND OF ACCESS-

SORY MINERALS IN CERTAIN GRANITES]: *Geokhimiya*, no. 2.

118. Galuzo, Yu. V., O VOZMOZHNOСТИ KOLICHESTVENNOGO OPREDELENIYA BORA V PORODAKH NEYTRONNOM GAMMA-METODAM [THE POSSIBILITY OF MAKING A QUALITATIVE DETERMINATION OF BORON IN ROCKS BY THE NEUTRON GAMMA METHOD]: *Izv. vyssh. uchebn. zaved., ser. neft' i gaz*, no. 1.
119. Ginzburg, A.I., L.G. Fel'dman and O.D. Stavrov, REDKIYE ELEMENTY V IZERZHENNYKH GORNYKH PORODAKH (K ITOGAM SIMPOZIUMA PO GEOKHIMII REDKIKH ELEMENTOV V SVYAZI S PROBLEMOY PETROGENEZISA) [RARE ELEMENTS IN ERUPTIVE ROCKS (FROM REPORTS AT THE SYMPOSIUM ON THE GEO-CHEMISTRY OF RARE ELEMENTS ASSOCIATED WITH THE PETROGENESIS PROBLEM)]: *Sov. Geol.* no. 4.
120. Govorov, I.N., METASOMATICHESKAYA ZONAL'NOST' DESILIKATSII PRI GREYZENIZATSII IZVESTNYAKOV [METASOMATIC ZONALITY OF DESILICONIZATION DURING THE GREISENIGATION OF LIMESTONES]: *Doklady, Akademiya Nauk SSSR*, t. 119, no. 3.
121. Demchuk, L.V., K MINERALOGICHESKOY KHA-RAKTERISTIKE YURSKIKH I MELOVYKH OTLOZHENIY SEVERNOGO I SEVERO-ZAPADNOGO PRIKASPIYA [THE MINERALOGY OF THE JURASSIC AND CRETACEOUS DEPOSITS IN THE NORTHERN AND NORTH-WESTERN CASPIAN REGION]: *Geol. Nefti*, no. 4.
122. Distanov, U.G. and N.V. Kirsanov, O KHA-RAKTERE I MINERALOGICHESKOM SOSTAVE TERRIGENNOY CHASTI NIZHNEAKCHAGYLSKIKH OTLOZHENIY VYATSKO-KAMSKOGO KRAYA [THE NATURE AND MINERALOGICAL COMPOSITION OF THE CONTINENTAL PORTION OF THE LOWER ASHGIL-LIAN DEPOSITS OF THE VYATKA-KAMA REGION]: *Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk*, no. 6, 1957.
123. Dyadchenko, M.G., K MINERALOGII CHETVERTICHNYKH OTLOZHENIY I KORY VYVETRIVANIYA KRISTAL-LICHESKIKH POROD BASSEYNA VER-KHNEGO TECHENIYA R. TETEREVA [THE MINERALOGY OF THE QUATERNARY DEPOSITS AND THE CORES OF WEATHERED CRYSTALLINE ROCKS FROM THE UPPER COURSES OF THE TETEREV RIVER]: *Geol. Zhurn., Akademiya Nauk UkrSSR*, t. 18, Vyp. 2.
124. Yershova, Z.P. and Ya. I. Ol'shanskiy, RAVNOVESIYE DVUKH ZHIDKIKH FAZ VO FTOR-SILIKATNYKH SISTEMAKH, SODERZHASHCHIKH SHCHELOCHNYYE METALLY [THE EQUILIBRIUM OF TWO LIQUID PHASES IN FLUORIDE-SILICATE SYSTEMS CONTAINING ALKALINE METALS]: *Geokhimiya*, no. 2.
125. Yeskin, A.S. and V.G. Belichenko, O PALEOZOYSKIKH GRANITAKH BARGUZINSKOGO KHREBTA [PALEOZOIC GRANITES OF THE BARGUZINSKIY RANGE]: *Doklady, Akademiya Nauk SSSR*, t. 119, no. 1.
126. Zhirov, K.K., N.V. Baranovskaya, and L.A. Litvina, OPREDELENIYA ABSOLYUTNOGO GEOLOGICHESKOGO VOZRASTA GELIYEVYM METODOM PO MONATSITAM [DETERMINATION OF ABSOLUTE GEOLOGICAL AGE BY THE HELIUM METHOD IN MONAZITE]: *Geokhimiya*, no. 2.
127. Zal'tsman, I.G., O ZHELEZISTYKH PORODAKH KAYNOZOYA YUZHNOY CHASTI ZAPADNO-SIBIRSKOY NIZMENNOSTI [THE FERRUGINOUS CENOZOIC ROCKS IN THE SOUTHERN PART OF THE WEST SIBERIAN PLAIN]: *Vestn. Zap.-Sib. Geol. Upr.*, Vyp. 2, 1957.
128. Zaridze, G.M., PETROSTRUKTURNYYE ISSLEDOVANIYA KRISTAL-LICHESKIKH POROD CHASTI DOLINY R. BAKSANA SEVERNOM KAVKAZE [PETROSTRUCTURAL STUDIES OF THE CRYSTALLINE ROCKS IN A SECTION OF THE BAKSAN RIVER VALLEY IN THE NORTHERN CAUCASUS]: *Byul., MOIP, Otd. Geol.*, t. 33, Vyp. 2.
129. Zelyanskaya, A.I. and N.V. Bausova, POLYAROGRAFICHESKOYE ISSLEDOVANIYE SALITSILATNOGO KOMPLEKSA GALLIYA [POLAROGRAPHIC STUDIES OF THE GALLIUM SALICY-LATE COMPLEX]: *Izv. Sib. Otd., Akademiya Nauk SSSR*, no. 3.
130. Ivanova, V.P. and N.A. Kornilov, ASBESTOVIDNYY (POPERECHE-NOVOLOKNISTYY) KHLORIT IZ MEDNONIKELEVOGO MESTOROZHDENIYA [ASBESTOS-LIKE (LONG-FIBERED) CHLORITE FROM COPPER-NICKEL DEPOSITS]: *Doklady, Akademiya Nauk SSSR*, t. 119, no. 1.

# BIBLIOGRAPHY

31. Kaveyev, M.S., OPREDELENIYE VELICHINY pH OSADKOBOBRAZOVANIYA V ZONE KHIMICHESKOY OSADOCHNOY DIFFERENTSIIATSII [THE pH DETERMINATION OF SEDIMENTS IN A CHEMICAL SEDIMENTARY DIFFERENTIATION ZONE]: FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
32. Kalenov, A.D., K GEOKHIMII SKANDIYA V ZONE GIPERGEZEZA [THE GEOCHEMISTRY OF SCANDIUM IN A HYPERGENETIC ZONE]: Geokhimiya, no. 2.
33. Kapatsinskaya, L.A. and N.G. Syromyatnikov, K VOPROSU ISPOL'ZOVANIYA IONO-OBMENNYKH SMOL V RADIOKHIMICHESKOM ANALIZE PRIRODNYKH OB"YEKTOV [THE PROBLEM OF USING ION-EXCHANGE RESINS IN RADIOCHEMICAL ANALYSES OF NATURAL FEATURES]: Vest., Akademiya Nauk KazSSR, no. 4.
34. Katchenkov, S.M. and Ye. I. Flegontova, MALYYE KHIMICHESKIYE ELEMENTY V PORODAKH FUNDAMENTA VOSTOCHNOY CHASTI RUSSKOY PLATFORMY [TRACE ELEMENTS IN THE BASEMENT ROCKS OF THE EASTERN PART OF THE RUSSIAN PLATFORM]: Geokhimiya, no. 2.
35. Kim Chan-sun, K VOPROSU O PROTSESSE SERITSITIZATSII PLATIOKLAZOV V GRANITOIDAKH (NA PRIMERE CHUSOVSKOGO MASSIVA KVARTSEVYKH DIORITOV) [THE PROCESS OF PLAGIOCLASE SERICITIZATION IN GRANITOIDS (ON SAMPLES OF QUARTZ DIORITES FROM THE CHUSOVSKIY MASSIF)]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
36. Kogolina, L.P., L.G. Or'yev and R.A. Vladimirovskaya, SOSTAV I STRUKTURA POROD-KOLLEKTOROV NIZHNEGO MELA BEREZOVSKOGO RAYONA [THE COMPOSITION AND STRUCTURE OF THE LOWER CRETACEOUS RESERVOIR ROCKS IN THE BEREZORSKIY REGION]: Geol. Nefti, no. 4.
37. Kopeliovich, A.V., O MIKROSTILOLITAKH I NEKOTORYKH ROSTVENNYKH IM STRUKTURNYKH FORMAKH V PESCHANIKAKH MOGILEVSKOY SVITY YUGO-ZAPADA RUSSKOY PLATFORMY [MICROSTYLOLITES AND OTHER FORMS STRUCTURALLY RELATED TO THEM TYPICAL OF THE MOGILEVSKIY SANDSTONE FORMATION IN THE SOUTHWESTERN RUSSIAN PLATFORM]: Doklady, Akademiya Nauk SSSR, t. 119, no. 2.
138. Koptev-Dvornikov, V.S., Ye. V. Negrey, and M.G. Rub, NEKOTORYYE DANNYYE O RASPREDELENIY RASSEYANNYKH ELEMENTOV V GRANITOIDAKH KAZAKHSTANA [SOME DATA ON THE DISTRIBUTION OF RARE ELEMENTS IN THE KAZAKHSTAN GRANITOIDS]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
139. Korzhinskiy, D.S., RETSENZIYA NA KNIGU P. LAFFITA "VVEDENIYE V IZUCHENIYE METAMORFICHESKIKH POROD I RUDNYKH MESTOROZHDENIY. FIZICHESKAYA KHIMIYA I TERMODINAMIKA. PARIZH. 1957" [REVIEW OF P. LAFFITE'S BOOK, "INTRODUCTION TO THE STUDY OF METAMORPHIC ROCKS AND ORE DEPOSITS. CHEMISTRY AND THERMODYNAMICS. PARIS. 1957"]: Geokhimiya, no. 2.
140. Kuznetsov, Ye. A., GABBRO-PERIDOTITOVYYE FORMATSII URALA [GABBRO-PERIDOTITE FORMATIONS IN THE URALS]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
141. Kurochka, V.P., GALLUAZIT V FOSFORITONOSNYKH ARGILLITAKH DREVNEGO PALEOZOYA PRIDNESTROV'YA [HALLOYSITE IN THE PHOSPHOROUS ARGILLITES OF THE EARLY PALEOZOIC IN THE DNESTR RIVER AREA]: Doklady, Akademiya Nauk SSSR, t. 119, no. 2.
142. Lagutin, P.K. and G.A. Makukhina, K VOPROSU O VOZRASTE NEKOTORYKH EFFUZIVOV YUGO-ZAPADNOY CHASTI DONBASSA [THE AGE OF SOME OF THE EFFUSIVES IN THE SOUTHWESTERN PART OF THE DONBAS]: Doklady, Akademiya Nauk UkrSSR, t. 119, no. 2.
143. Lobanova, V.V., K KHKARAKTERISTIKE MINERALOGICHESKOGO SOSTAVA GIDROKHIMICHESKOY TOLSHCHI CHELKARSKOGO PODNYATIYA [THE NATURE OF THE MINERALOGICAL COMPOSITION OF THE HYDROCHEMICAL SERIES OF THE CHELKAR UPH-EAVAL]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
144. Marakushev, A.A., PARAGENEZISY IZVESTKOVYKH SKARNOV V TAYEZHNOY MAGNEZIAL'NOSKARNOVOM ZHELEZORUDNOM MESTOROSHDENIY V ARKHEYE ALDANSKOY PLITY [THE PARAGENESIS OF LIMESTONE SEAMS IN THE TAYEZH MAGNESIAN-SKARN IRON ORE DEPOSITS IN THE ARCHEAN OF THE ALDAN BLOCK]: Geo-

khimiya, no. 2.

145. Marfunin, A.S., NOVAYA DIAGRAMMA OPTICHESKOY ORIYENTIROVKI KISLYK I SREDNIKH PLAGIOKLAZOV [NEW DIAGRAM FOR THE OPTICAL ORIENTATION OF ACID AND INTERMEDIATE PLAGIOCLASES]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
146. Markhinin, Ye. K., O KOLICHESTVE YUBENIL'NOY VODY, UCHASTVU-YUSHCHEY V VULKANICHESKIKH VZRYVAKH [THE AMOUNT OF WATER PARTICIPATING IN VOLCANIC EXPLOSIONS]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
147. Miropol'skiy, L.M., O NEKOTORYKH FUNDAMENTAL'NYKH VOPROSAKH MINERALOGII [SOME FUNDAMENTAL PROBLEMS OF MINERALOGY]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
148. Miropol'skiy, L.M., YUBILEY [JUBILEE]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
149. Petelin, V.P., and E.A. Ostroumov, O NEKOTORYKH OSOBNOSTYAKH RASPREDELENIYA ZHELEZA V OSADKAKH OKHOTSKOGO MORYA [SOME PECULIARITIES IN THE DISTRIBUTION OF IRON IN THE OKHOTSK SEA SEDIMENTS]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
150. Pil'tenko, M.K., PETROKHIMICHESKIYE KOORDINATY I POLYA INTRUZIVNYKH POROD [THE PETROCHEMICAL COORDINATES AND POLARITY OF INTRUSIVE ROCKS]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
151. Rabinovich, A.V., A.N. Murav'yeva and M.V. Zhdanova, SODERZHANIYE MOLIBDENA V NEKOTORYKH PORODAKH I MINERALAKH INTRUZIVNYKH OBRAZOVANIY VOSTOCHNOGO ZABAYKAL'YA [THE MOLYBDENUM CONTENT IN SOME OF THE ROCKS AND MINERALS OF THE INTRUSIVE FORMATIONS OF THE EASTERN TRANS-BAYKAL REGION]: Geokhimiya, no. 2.
152. REZYUME OSNOVNYKH STATEY V ZHURN. "GEOCHIMICA ET COSMOCHIMICA ACTA, T. 13, NO. 2/3" [ABSTRACTS OF THE LEADING ARTICLES IN THE JOURNAL, GEOCHIMICA ET COSMOCHIMICA ACTA, VOL. 13, NO. 2/3]: Geokhimiya, no. 2.
153. Rodionov, S.P., PEGMATITY CHARNOKITOVOY SERII PODOLII [THE PEGMATITES OF THE CHARNOKIT SERIES IN PODOLIYA]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
154. Rozhkova, Ye. V. and M.B. Serebryakova, VOZMOZHNAYA ROL' SORBTsii V OBRAZOVANII OREOLOV RASSEYANIYA [THE POSSIBLE ROLE OF SORPTION IN THE FORMATION OF DISPERSION HALOS]: Sov. Geol., no. 4.
155. Ryabenko, V.A., K VOPROSU O SOSTAVE I STRATIGRAFICHESKOM POLOZHENII METAMORFICHESKIKH I MAGMATICHESKIKH POROD BASSEYNA R. SOBI [THE COMPOSITION AND STRATIGRAPHY OF THE METAMORPHIC AND MAGMATIC ROCKS OF THE SOBI RIVER BASIN]: Geol. Zhurn., Akademiya Nauk USSR, vol. 18, issue 2. In Ukrainian. Abstract in Russian.
156. Sementovskiy, Yu. V., O ZAVISIMOSTI PLOSHCHADI DIFFERENTSIAL'NOY TERMOGRAFIKESKOY ZAPISI OT RASPREDELENIYA V OBRAZTSIE TERMOAKTIVNOGO VESHCHESTVA [THE RELATIONSHIP OF THE RECORDED PATTERN IN DIFFERENTIAL THERMOGRAPHIC ANALYSIS TO THE DISTRIBUTION OF THERMOACTIVE MATERIAL IN A SAMPLE]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
157. ———, TERMOGRAFIKESKAYA USTANOVKA [THERMOGRAPHIC APPARATUS]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
158. Simonov, V.N. and N.V. Belov, KRISTALLICHESKAYA STRUKTURA AMBLIGONITA [THE CRYSTAL STRUCTURE OF AMBLYGONITE]: Doklady, Akademiya Nauk SSSR, t. 119, no. 2.
159. Skopintsev, B.A. et. al., SOLEVOY SOSTAV VODY CHERNOGO MORYA [THE SALINITY OF THE BLACK SEA]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
160. Slepnev, Yu. S., OSOBNOSTI RASPROSTRANENIYA LITIYA I RUBIDIYA V NEKOTORYKH GRANITOIDAKH YAKUTII [THE PECULIARITIES OF DISTRIBUTION OF LITHIUM AND RUBIDIUM IN CERTAIN GRANITOIDS OF YAKUTIYA]: Geokhimiya, no. 2.
161. Smol'yaninov, N.A., NEKROLOG [OBITUARY]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.

# BIBLIOGRAPHY

62. Solov'yev, A.T. and Ye. P. Levando, GEARKSUTIT IZ VOSTOCHNOGO ZABAYKALYA [GEARKSUTITE FROM EASTERN TRANS-BAYKAL]: Doklady, Akademiya Nauk SSSR, t. 119, no. 1.
63. Sosipatrov, T.M., O FORMIROVANII TENARDITA V SUL'FATNOKHLORID-NYKH OZERAKH KULUNDINSKOY STEPI [THE FORMATION OF TENARDITE IN THE SULFATE-CHLORIDE LAKES OF THE KULUNDINSKAYA STEPPE]: Izv. Sib. Otd., Akademiya Nauk SSSR, no. 3.
64. Starik, I. Ye. and L.A. Litvina, PRIMENENIYE METODA VYSHCHE-LACHIVANIYA DLYA OTSENKI PRIGODNOSTI OBRAZTSOV PRI OPREDELENII VOZRASTA ARGONOVYM METODOM [APPLICATION OF THE LEACHING METHOD IN EVALUATING THE SUITABILITY OF SAMPLES FOR THE ARGON AGE DETERMINATION METHOD]: Geokhimiya, no. 2.
65. Tauson, L.V., SIMPOZIUM PO GEO-KHIMII REDKIKH ELEMENTOV V SVYAZI S PROBLEMAI PETROGENEZISA [SYMPOSIUM ON THE GEO-CHEMISTRY OF RARE ELEMENTS IN CONNECTION WITH THE PETROGENESIS PROBLEM]: Geokhimiya, no. 2.
66. Tsarovskiy, I.D., PO POVODU STAT'YI S.A. RUDENKO "O SPOSOBE I MEKHANIZME OBRAZOVANIYA KRISTALLOV TSIRKONA V MARIUPOLITE [APPROPOS S.A. RUDENKO'S PAPER, "THE METHOD AND MECHANICS OF ZIRCON CRYSTAL FORMATION IN MARIUPOLITE]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
67. Shilov, V.N., N.N. Belikova and Z.P. Yershova, O PRIMENIMOSTI METODA PLYAVLENIYA DLYA OPREDELENIYA Priblizitel'nogo Khimicheskogo sostava kaynozoy-skiykh vulkanicheskikh porod yuzhnogo sakhalina [THE APPLICATION OF THE FUSION METHOD TO DETERMINE THE APPROXIMATE CHEMICAL COMPOSITION OF CENOZOIC VOLCANIC ROCKS IN SOUTHERN SAKHALIN]: Doklady, Akademiya Nauk SSSR, t. 119, no. 2.
68. Yurkevich, I.A. and V.A. Feyrabent, NEKOTORYYE ZAKONOMERNOSTI IZMENENIYA pH POROD MEZOKAYNOZOYSKOY TOLSHCHI VOSTOCHNOGO ZAURAL'YA [SOME RULES GOVERNING THE CHANGE IN pH OF THE MESO-CENOZOIC SERIES IN THE EASTERN TRANS-URALS]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
69. Abdullayev, R.N. et al., OSNOVNYYE CHERTY METALLOGENII AZER-BAYDZHANA [BASIC FEATURES OF THE METALLOGENY OF AZER-BAYDZHAN]: Sov. Geol., no. 4.
70. Akhundov, A.R., KONTROL' REZUL'TATOV KHIMICHESKOGO ANALIZA VOD NEFTYANYKH MESTOROZH-DENIY [CONTROL OF THE RESULTS OF CHEMICAL ANALYSES OF WATER IN OIL DEPOSITS]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 3.
71. Aver'yanov, V.I., O PERSPEKTIVAKH NEFTENOSNOSTI DEVONSKIKH OTLOZHENIY SEVERO-VOSTOKA ZAKAMSKOY CHASTI TATARII [THE PETROLEUM POTENTIAL OF THE DEVONIAN DEPOSITS IN THE NORTH-EASTERN TRANS-KAMA PART OF TATARIIA]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
72. Aliyev, A.K., O.T. Ovsepyan and D.A. Dzhevanshir, K VOPROSU PERSPEKTIV NEFTEGAZONOSNOSTI MESTOROZH-DENIYA BABAZANAN [THE OIL AND GAS POTENTIAL OF THE BABAZANAN DEPOSITS]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 1.
73. Brodsky A.A., KHIMIYA PODZEMNYKH VOD I YEYE ZNACHENIYE DLYA POISKOV RUDNYKH MESTOROZH-DENIY [THE CHEMISTRY OF GROUND WATER AND ITS SIGNIFICANCE IN PROSPECTING FOR ORE DEPOSITS]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
74. Vasil'yev, Yu. M., PERSPEKTIVY NEFTEGAZONOSNOSTI POLUOSTROVA BUZACHI V SVETE NOVYKH DANIYKH [THE OIL AND GAS POTENTIAL OF THE BUZACHI PENINSULA ACCORDING TO NEW DATA]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razved., no. 2.
75. Vladover, M.N., GIDROGEOLOGICHE-SKIYE USLOVIYA TUYMAZINSKOGO NEFTYANOGO MESTOROZH-DENIYA I PROYEKT OPYTNYKH RABOT DLYA VYYASNENIYA SVYAZI MEZHDU DVUMYA EKSPLUATATSIONNYMI

- GORIZONTAMI  $D_1$  AND  $D_{II}$  [HYDRO-  
GEOLOGICAL CONDITIONS OF THE  
TUYZMAZINSKIY OIL DEPOSITS AND  
THE EXPERIMENTAL WORK PRO-  
JECT TO EXPLAIN THE CONNECTION  
BETWEEN THE TWO PRODUCING  
HORIZONS,  $D_1$  AND  $D_{II}$ ]: Report  
Izv. Vyssh. Uchebn. Zaved., Ser.  
Geol. i Razv., no. 2.
176. Vol'fson, F.I. and L.I. Lukin, IZU-  
CHENIYE STRUKTUR ENDOGENNYKH  
RUDNYKH POLEY I MESTOROZHDENIY  
[A STUDY OF THE STRUCTURE OF  
ENDOGENIC ORE FIELDS AND  
DEPOSITS]: Vestn., Akademiya Nauk  
SSSR, no. 4.
177. Goretskiy, Yu. K., O KLASSIFIKATSII  
BOKSITOV [THE CLASSIFICATION OF  
BAUXITES]: Byul., MOIP, Otd. Geol.,  
t. 33, Vyp. 2.
178. Grishin, G.L., I.P. Karasev and A.I.  
Kononov, GAZONOSNOST' NIZHNE-  
KEMBRIYSKIKH OTLOZHENIY PAR-  
FENOVSKOY PLOSHCHADI [GAS  
OCCURRENCE IN THE LOWER CAM-  
BRIAN DEPOSITS OF THE PARFE-  
NOVSKIY FIELD]: Geol. Nefti, no. 4.
179. Dedeyev, V.A., O NEFTENOSNOSTI  
PALEOZOYSKIKH OTLOZHENIY  
SHCHUCHVINSKOGO RAYONA [PETRO-  
LEUM IN THE PALEOZOIC DEPOSITS  
OF THE SHCHUCHVINSKIY REGION]:  
Geol. Nefti, no. 4.
180. Durmish'yan, A.G., GAZOKONDENSAT-  
NAYA ZALEZH' NA PLOSHCHADI  
KARADAG [GAS CONDENSATION  
OCCURRENCE IN THE KARADAG  
FIELD]: Geol. Nefti, no. 4.
181. Zaridze, G.M., PROISKHOZHDENIYA  
GRANITOIDOV I IKH RUDONOSNOST'  
NA PRIMERE KAVKAZA [ORIGIN OF  
GRANITIDS AND THEIR ORES,  
ACCORDING TO A SAMPLE FROM  
THE CAUCASUS]: Sov. Geol., no. 4.
182. Kalugin, A.S. and A.S. Mukhin, ITOGI  
RABOTPO ZHELEZNYM RUDAM  
ZAPADNOY SIBIRI K 40-LETIYU  
OKTYABR'SKOY REVOLYUTSII [RE-  
SULTS OF STUDIES ON THE IRON  
ORES OF WESTERN SIBERIA ON THE  
40TH ANNIVERSARY OF THE OCTO-  
BER REVOLUTION]: Vestn., Zap. -  
Sib. Geol. Upr., Vyp. 2, 1957.
183. Kirsanov, N.V., K VOPROSU O MIN-  
ERALOGICHESKOM SOSTAVE BOK-  
SITOVYKH ZALEZHEY SHENUROV-  
SKOGO MESTOROZHDENIYA TUL'  
SKOY OBLASTI [THE MINERALOGI-  
CAL COMPOSITION OF THE BAUXITE  
DEPOSITS OF THE SHENUROVSKIY  
FORMATIONS OF TULA OBLAST']: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
184. Kozlov, V., O STAT'YE G.A. KHEL'  
KVISTA "USLOVIYA FORMIROVANIYA  
I KRITERII POISKOVA ZALEZHEY  
NEFTI I GAZA" [ON THE ARTICLE  
BY G.A. KHEL'QVIST, CONDITIONS  
OF FORMATION AND PROSPECTING  
CRITERIA FOR OIL AND GAS  
DEPOSITS]: Geol. Nefti, no. 4.
185. Korenevskiy, S.M. and Yu. S. Goryunov,  
GEOLOGICHESKOYE STROYENIYE,  
KALIYENOSNOST' I BORONOSNOST'  
CHELKARSKOY SOLYANOY STRUK-  
TURY [GEOLOGICAL STRUCTURE,  
THE SODIUM AND BORON CONTENT  
OF THE CHELKAR SALT STRUC-  
TURE]: Doklady, Akademiya Nauk  
SSSR, t. 118, no. 6.
186. Kuznetsova, N.P., and V.P. Kazarinov,  
GEOFIZICHESKIYE METODY RAZVEDKI  
V POZNANII REGIONAL'NOGO GEO-  
LOGICHESKOGO STROYENIYA ZAPAD-  
NO-SIBIRSKOY NIZMENNOSTI [GEO-  
PHYSICAL METHODS OF EXPLORA-  
TION AND INFORMATION ABOUT  
THE REGIONAL GEOLOGICAL STRUC-  
TURE OF THE WESTERN SIBERIAN  
PLAIN]: Geol. Nefti, no. 4.
187. Kulakov, A.I. and N.S. Mozhayev, O  
NEFTENOSNOSTI TERRIGENNOGO  
KOMPLEKSA NIZHNEGO KARBONA  
NA TERRITORII ORENBURSKOY  
OBLASTI [THE PETROLEUM IN THE  
LOWER CARBONIFEROUS CONTINEN-  
TAL COMPLEX IN THE ORENBURG  
AREA]: Geol. Nefti, no. 5.
188. Kurdyukov, A.A., MOLIBDENOVOYE  
ORUDENIENIYE V ROGOVIKAKH  
MESTOROZHDENIYA TYRNYAUZ  
[MOLYBDENUM ORES IN THE CHERT  
DEPOSITS OF TYRNYAUZ]: Izv.  
Vyssh. Uchebn. Zaved., Ser. Geol.  
i Razv., no. 2.
189. Levi, V.A., K VOPROSU O OPISKAKH  
ZONY VYKLINIVANIYA PRODUKTIV-  
NOY TOLSHCHI V MUGANSKOY  
STEPI [THE PROBLEM OF ESTIMA-  
TING THE TAPER ZONE OF THE  
PRODUCING FORMATION IN THE  
MUGANSKAYA STEPPE]: Az. Neft.  
khaz., no. 3 (381).
190. Lobov, V.A., G.I. Alekseyev and M.I.  
Zaydel'son, PERSPEKTIVY NEFTE-  
GAZONOSNOSTI PALEOZOYSKIKH  
OTLOZHENIY KUYBYSHEV, OREN-

## BIBLIOGRAPHY

- BURG AND ULYANOV AREAS]: Geol. Nefti, no. 5.
- Luginets, I. P., PROBLEMA NEFTEGA-ZONOSNOSTI MEZOZOYA NIVOZ'YEV YENISEYA [THE PROBLEM OF THE OIL AND GAS IN THE MESOZOIC OF THE LOWER YENISEY]: Sov. Geol., no. 4.
- Mavritsky, B. F., OB ISTORII RAZVITIYA ZAPADNO-SIBIRSKOGO ARTEZIAN-SKOGO BASSEYNA I PERSPECTIVY YEGO NEFTEGAZONOSNOSTI [HISTORICAL DEVELOPMENT OF THE WEST SIBERIAN ARTESIAN BASIN AND ITS OIL AND GAS POTENTIALITIES]: Geol. Nefti, no. 4.
- Magakyan, L. B., NEKOTORYYE ZAMECHANIYA PO RAZVEDKE KADZHARANSKOGO MESTOROZHDENIYA [A FEW COMMENTS ABOUT THE EXPLORATION OF THE KADZHARAN-SKIY DEPOSITS]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
- Maksimov, M. M., OSOBNOSTI FORMIROVANIYA DEVONSKIKH OTLOZHENIY (PLAST D<sub>1</sub>) BAVLINSKOGO NEFTYANOGO MESTOROZHDENIYA I METODIKA IKH IZUCHENIYA S POMOSHCH'YU ZONAL'NYKH KART [THE NATURE OF THE FORMATION OF THE DEVONIAN DEPOSIT (STRATUM D<sub>1</sub>) OF THE BAVLINSKIY OIL DEPOSITS AND A METHOD TO STUDY IT USING ZONAL MAPS]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 3.
- Maloletko, A. M., NOVYYE DANNYYE O YURSKIKH UGLENOSNYKH OTLOZHENIYAKH V ALTAYSKOM KRAYE [NEW DATA ON THE JURASSIC COAL DEPOSITS IN ALTAY KRAY]: Vest. Zap.-Sib. Geol. Upr., Vyp. 2, 1957.
- Martirosyan, R. A., K GENEZISU SER-NOKOLCHEDANNYKH MESTOROZH-DENIY VANKLU-ARUTYUNO-GOMER-SKOGO RUDNAGO POLYA [THE ORIGIN OF THE SULFATE-PYRITE DEPOSITS IN THE VANKLU-ARUTYUN--GOMERSKIY ORE FIELDS]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 3.
- Melik-Pashayev, V. S., NEKOTORYYE VOPROSY FORMIROVANIYA NEFTYANYKH ZALEZHEY APSHERONSKAY NEFTENOSNOY OBLASTI [A FEW PROBLEMS ABOUT THE FORMATION OF OIL-BEARING STRATA IN THE APSHERON OIL FIELD]: Sov. Geol., no. 4.
198. Mukhin, A. S. and P. P. Ladygin, NOVYYE DANNYYE PO GEOLO-PROMYSHLENNY KHA-KTERISTIKE USINSKOGO MESTOROZH-DENIYA MARGANTSOVYKH RUD [NEW DATA ON THE GEOLOGIC-INDUSTRIAL CHARACTERISTICS OF THE USINSK MANGANESE ORE DEPOSITS]: Vest. Zap.-Sib. Geol. Upr., Vyp. 2, 1957.
199. Nezimov, V. N., TEKHNOLOGICHESKAYA KHA-KTERISTIKA TSEMENTNOGO SYR'YA SHUGUROVSKOY GRUPPY MESTOROZH-DENIY [TECHNOLOGICAL NATURE OF THE RAW MATERIALS FOR CEMENT IN THE SHUGUROVSK GROUP OF DEPOSITS]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
200. NEFT' V SAMGORSKOY STEP'I [OIL ON THE SAMGORSK STEPPE]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 3.
201. NOVOYE MESTOROZH-DENIYE GAZA NA UKRAINE [NEW OCCURRENCES OF GAS IN THE UKRAINE]: Izv. Vyssh. Uchebn. Zaved., Ser. Neft' i Gaz, no. 3.
202. Ozerskiy, A. F., GEOLOGICHESKOYE STROYENIYE INKURSKOGO VOL-FRAMOVOGO SHTOKVERKA I PRO-YEKT DETAL'NOY RAZVEDKI YEGO SEVERNOGO FLANGA [GEO-LOGICAL STRUCTURE OF THE IN-KURSK TUNGSTEN STOCKWORK AND A PROJECT FOR DETAILED EX-PLO-RATION OF ITS NORTHERN SIDE]: Referat. Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
203. Pavlus', E. V., GEOLOGICHESKOYE STROYENIYE I PROYEKT RAZVEDKI GAZONOSNOSTI POROD KUKISVUM-CHOPRSKOGO APATITOVOGO MES-TOROZH-DENIYA [THE GEOLOGICAL STRUCTURE AND A PROJECT TO PROSPECT FOR GAS IN THE KUKIS-VUMCHARRSKIY APATITE DEPOSITS]: Referat. Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
204. Pritula, Yu. A. et al., PUTI PRAK-TICHESKOGO RESHENIYA PROBLEMY NEFTEGAZONOSNOSTI YUGA SIBIR-SKOY PLATFORMY [METHODS FOR THE PRACTICAL SOLUTION OF THE PROBLEM OF OIL AND GAS IN THE SOUTHERN SIBERIAN PLATFORM]: Geol. Nefti, no. 4.
205. Prusevich, A. M., KIYSKOYE MESTO-RZH-DENIYE URTITOV [THE KIYSKOYE URTITE DEPOSIT]: Vest. Zap. - Sib.

Geol. Upr., Vyp. 2, 1957.

Ser. Geol. i Razv., no. 2.

206. Rozanov, L.N. and G. P. Ovanesov, PERSPECTIVY NEFTEGAZONOSNOSTI PALEOZOYSKIKH OTLOZHENIY BASH-KIRII [OIL AND GAS POTENTIALS OF THE BASHKIR PALEOZOIC DEPOSITS]: Geol. Nefti, no. 5.
207. Rusinov, L. A., STRATIGRAFICHESKOYE RASPREDELENIYE FOSFORITOVYKH ZALEZHEY [THE STRATIGRAPHIC DISTRIBUTION OF PHOSPHATE DEPOSITS]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
208. Svishchev, M.F., NEFTEGAZONOSNOST' DEVONSKIKH, KAMENNOUGOL'NYKH I PERMSKIKH OTLOZHENIY ORENBURGSKOY OBLASTI [THE OIL AND GAS IN THE DEVONIAN, CARBONIFEROUS, AND PERMIAN DEPOSITS IN THE ORENBURG AREA]: Geol. Nefti, no. 5.
209. Spanderashvili, G.I., NOVYYE DANNYYE O FOSFORITONOSNOSTI GORNOY SHORII [NEW DATA ON THE PHOSPHATES IN GORNAYA SHORIYA]: Vest. Zap.-Sib. Geol. Upr., Vyp. 2, 1957.
210. Sukharina, A.N., MINERALNO-SYR'-YEVAYA BAZA ALYUMNIYEVOY PROMYSHLENNOSTI V ZAPADNOY SIBIRI K 40-LETIYU OKTYABR'SKOY REVOLYUTSII [THE RAW MATERIAL -- MINERAL BASE FOR THE ALUMINUM INDUSTRY IN WESTERN SIBERIA ON THE 40TH ANNIVERSARY OF THE OCTOBER REVOLUTION]: Vestn. Zap.-Sib. Geol. Upr., Vyp. 2, 1957.
211. Treshchetenkov, M.N., KOLLEKTORSKIYE SVOYSTVA POROD USHAKOVSKOY I MOTSKOY SVIT NIZHNEGO KEMBRIYA YUZHNOY CHASTI SIBIRSKOY PLATFORMY [RESEVOIR PROPERTIES OF THE ROCKS IN THE USHAKOV AND MOTSKOY FORMATIONS OF THE LOWER CAMBRIAN IN THE SOUTHERN PART OF THE SIBERIAN PLATFORM]: Geol. Nefti., no. 4.
212. CHZHAO PEN-DA, NEKOTORYYE GEOLOGICHESKIYE OSOBENNOSTI I METODIKA RAZVEDKI OLOVYANNYKH I VOL'FRAMOVYKH MESTOROZHDENIY SHTOKVERKOVOGO TIPA [A FEW GEOLOGICAL PECULIARITIES AND METHODS OF PROSPECTING FOR TIN AND TUNGSTEN DEPOSITS OF THE STOCKWORK TYPE]: Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
213. Shipulin, F.K., SOOTNOSHENIYA INTRUZIY I ORUDENENIYA V ZYRYANSKOM RAYONE NA RUDNOM ALTAYE [THE RELATIONSHIP BETWEEN INTRUSION AND MINERALIZATION IN THE ZYRYANSK REGION OF THE RUDNYY ALTAY]: Doklady, Akadem. Nauk SSSR, t. 119, no. 3.
214. Shpil'man, I. A., NEKOTORYYE DANNYYE PO NEFTENOSNOSTI DEVONSKIKH OTLOZHENIY V ZAKAMSKOY TATARII [SOME DATA ON THE OIL IN THE DEVONIAN DEPOSITS OF THE TRANS-KAMA TATARIIA]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
215. Yusupov, B.M., NEKOTORYYE VOPROSY TEKTONIKI I NEFTENOSNOSTI TATARII [SOME PROBLEMS ON THE TECTONICS AND OIL OF TARTARIA]: Izv. Kazansk. FAN SSSR, Ser. Geol. Nauk, no. 6, 1957.
216. Yakovlev, I. A., GEOFIZICHESKIYE ISSLEDOVANIYA V RAYONE KHANT-MANSIYSKA S TSEL'YU POISKOV STRUKTUR BLAGOPRIYATNYKH DLYA SKOPLENIYA NEFTI [GEOPHYSICAL INVESTIGATIONS IN THE KHANT-MANSIYSK REGION TO DISCOVER STRUCTURES FAVORABLE TO THE ACCUMULATION OF OIL]: Referat. Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.

# HYDROGEOLOGY, ENGINEERING GEOLOGY

217. Babinets, A. Ye., OB OSOBENNOSTYAKH GIDROKHIMII PODZEMNYKH VOD ZAMEDLENNOGO VODOOBMENAYUGO-ZAPADNOY CHASTI RUSSKOY PLATFORMY [THE PECULIARITIES OF THE HYDROCHEMISTRY OF GROUND WATERS, OF RETARDED CIRCULATION IN THE SOUTHWESTERN PART OF THE RUSSIAN PLATFORM]: Geol. Zhurn., Akademiya Nauk UkrSSR, t. 18, Vyp. 2.
218. Belyakova, Ye. Ye., MIGRATSIYA METALLOV V PODZEMNYKH I POVERKHNOSTNYKH VODAKH VERKHNOKAYRAKTINSKOGO RAYONA V TSENTRAL'NOM KAZAKHSTANE [THE SUBTERRANEAN MIGRATION OF METALS AND SURFACE WATER IN THE UPPER KAYRAKTINSK REGION IN CENTRAL KAZAKHSTAN]: Geokhimiya, no. 2.

## BIBLIOGRAPHY

- Konoplyantsev, A.A. and A.G. Vladi-mirov, ISPOL'ZOVANIYE PODZEM-NYKH VOD DLYA OROSHENIYA [THE USE OF GROUND WATER FOR IRRIGATION]: Sov. Geol., no. 4.
- Makarenko, F.A., GORYACHIYE POD-ZEMNYYE VODY, IKH RASPROSTRA-NENIYE I PERSPEKTIVY PRAKTI-CHESKOGO ISPOL'ZOVANIYA [HOT GROUND WATER, DISTRIBUTION, AND PROSPECTS FOR PRACTICAL UTILIZATION]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
- Musayev, A.A., GIDROGEOLOGICHE-SKOYE RAYONIROVANIYE SHIRVAN-SKOY STEPİ [HYDROGEOLOGICAL REGIONAL CLASSIFICATION OF THE SHIRVANSKAYA STEPPE]: Doklady, Akademiya Nauk AzSSR, t. 14, no. 5.
- Podkolzina, A.V., INZHENERNO-GEOLOGICHESKAYA KHARAKTERIS-TIKA USLOVIY GORODSKOGO STROITEL'STVA V ODNOM IZ RA-YONOV ZABAYKAL'YA, NEOBKHO-DIMYYE PROTIVOEROZIONNYYE MEROPRIYATIYA I PROYEKT DOPOL-NITEL'NYKH ISSLEDOVANIY [THE ENGINEERING-GEOLOGICAL CHAR-ACTERISTICS OF TOWN CONSTRUC-TION CONDITIONS IN ONE OF THE TRANS-BAYKAL REGIONS, NECES-SARY MEASURES AGAINST EROSION, AND A PROJECT FOR SUPPLEMENT-ARY STUDIES]: Referat. Izv. Vyssh. Uchebn. Zaved., Ser. Geol. i Razv., no. 2.
- Ryzhikov, D.V., O BARRAZHAKH V KARSTOVYKH OBLASTYAKH I IKH GIDROGEOLOGICHESKOM ZNACHENII [BARRAGES IN KARST AREAS AND THEIR HYDROGEOLOGICAL SIGNI-FICANCE]: Doklady, Akademiya Nauk SSSR, t. 119, no. 3.
- Semikhatov, A.N., NEKROLOG [OBI-TUARY]: Byul., MOIP, Otd. Geol., t. 33, Vyp. 2.
- Tkachuk, V.G., O TIPAKH TERM SAYANO-BAYKAL'SKOY GORNOY STRANY [TYPES OF HOT SPRINGS IN THE SAYAN-BAYKAL MOUNTAIN-IOUS REGION]: Doklady, Akademiya Nauk SSSR, t. 118, no. 6.
- B. Papers in "Materialy," "Trudy," "Uchenyye Zapiski" and "Sborniki"
- Nauchnyye Trudy Moskovskogo Gornogo Instituta [Scientific Transactions of the Moscow Mining Institute]: Collec-tion 18. M., 1957. 254 pp. From the contents: Borshch-Kompaneyets, V.I., Study of the tectonic fractures in deposit "A".
2. Problemy Rudnykh Mestorozhdeny [The problems of ore deposits]: M. Izd. -vo In. Lit-ry. 1958. 495 pp. Contains: Bateman, A., The journal of economic geology. Turner, F.S., Metallogenic provinces and epochs. Hoyt, D., Thermal springs and epithermal ore deposits. Noble, J., The classification of ore deposits. McKinstry, G.I., Structures of hydrothermal ore depos-its. Park, Ch., Theory of the zonality of ore deposits. Lovering, T.S., The temperature within and near intrusions. Vale, V.A., Synthetic minerals. Shwartz, T., Hydrothermal changes in country rocks as prospecting cri-teria. Anderson, Ch., Oxidation of copper sulfides and secondary sulfide enrichment. Ingerson, E., Methods and problems of geological thermome-try. Krauskopf, K., Sedimentary de-posits of rare metals. McKelvey, V., D. Everhart and R. Harrels, Origin of uranium deposits.
  3. Trudy Voronezhskogo Universiteta [Trans-actions of Voronezh University]: t. 60, Vyp. 3. Sb. Rabot po. Est. Nauk am. Voronezh [Research collection on natural sciences at Voronezh] 1957, 108 pp. From the contents: Kozlov, M.T., Discovery of minium in the lead deposits of West Tuva. Andreyeva, N.S., Petrographic characteristics of the Quaternary deposits outcropping near the village of Krivobor'ye in the Voronezh area.
  4. Trudy Dal'nevostochnogo Filiala AN SSSR, ser. khim., [Transactions of the Far-Eastern Branch of the U.S.S.R. Acad-emy of Sciences, Chemistry Series]: Vyp. 3. M., 1958. 128 pp. From the contents: Bykov, V.T., The history of the study of natural absorbents in the Soviet Far East. Ustinovskiy, Yu. B. and V.G. Sakhno, A brief geological description of naturally absorbent deposits in the southern part of the Soviet Far East. Maleyev, Ye. F., The physical-chemical properties of tuff decomposition products from the ancient volcanos of the Amur-Ussury Plain. Maleyev, Ye. F., Tuffogenic facies of the Suyfunsкая Series, and the laws governing the distribution of their economic deposits. Bykov, V.T., The theory of the bleaching action of catalytic earths. Bykov, V.T. and L.V. Smirnova, The physical-chemical

and adsorptive properties of the natural absorbents in the Far East. Zalevskiy, N.I. and V.T. Vykov, Studies on the porous structure of natural absorbents by the mercury impregnation method. Presnyakova, O. Ye., The adaptation of the dynamic method to a study of the structure and a specific surface area of natural absorbents in the Far East. Bykov, V.T., Change in properties of natural absorbents during the weathering process.

5. Trudy Instituta Geologii Rudnykh Mestorozhdeniy, Petrografii, Mineralologii i Geokhimii AN SSSR [Transactions of the Institute for the Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Academy of Sciences of the U.S.S.R.]: Vyp. 13. M., 1958. 91 pp. Contents: Zalesskiy, B.V., Methods of studying the physical-mechanical properties of rocks. Nikolayev, S.V., Mineralogical types of limestones and dolomites in Samara Luki. Zalesskiy, B.V. and Ye. A. Sanina, Studies of the differential porosity of carbonate rocks in Samara Luki. Nikolayev, S.V., Some results of studies on jointing in the rocks of Samara Luki. Nikolayev, S.V., Marly dolomites of the Upper Carboniferous in Samara Luki. Rozanov, Yu. A., A rational method of studying rock resistance to frost. Zalesskiy, B.V. and I.P. Timchenko, The structural-lithologic peculiarities and the physical-mechanical properties of the carbonate rocks of the Sokskiy deposit. Rozanov, Yu. A., Studies of the frost-resistant property of the carbonate rocks of the Sokskiy deposit after impregnation under initial vacuum. Merenkov, B.Ya. and K.I. Tolstikhina, The porosity of asbestos-bearing, ultrabasic rocks and their genetic significance. Rozanov, Yu. A., Deformation of barite under high pressure for high shrinkage. Zheludev, I.S., Study of rock disintegration in rocks during experiments with dynamic pressures, using piezoelectric indicators.
6. Trudy Instituta Geologicheskikh Nauk AN USSR, ser. geofiz. [Transactions of the Institute of Geological Sciences of the Academy of Sciences of the Ukrainian SSR, geology series]: Vyp. 2, Kiev, 1958, 204 pp. From the contents: Subbotin, S.I., The nature of certain gravity anomalies in the Dnepr-Donets depression. Kravets, V.V., The use of seismic prospecting in the study of the tectonic structure

on the western margin of the Ovruchskiy Massif. Sobakar', G.I. The tectonics of the concealed portion of the Donbas-Priazovsky Massif junction, from geophysical data. Skopichenko, M.F., Some peculiarities in the geomagnetic and gravity anomaly fields in the central part of the Black Sea depression and their geological interpretation. Yurkevich, O.I., Endogenic factors in the tilting of the earth's crust. Galushko, P. Ya., Possible interpretations of gravity anomalies in various structures of the earth's crust. Golovtsyn, V.N., Interpretation of electrical prospecting in observations made when exploring for ore bodies. Lebedev, T.S., Some results of studies on the thickness of Paleozoic deposits in the Pripyat' depression. Krzhivanev, G.A., Density of the rocks from the Crimean Steppes and a few adjoining regions. Balabushevich, I.A., The regularity of thickness distribution in the sedimentary deposits of western Donbas. Garkalenko, I.A., Some data on the thickness of the carboniferous rocks in the western part of the Donets Basin. Kondrachuk, V. Yu., The thickness of the weathered crust of the Volinsk gabbro-labradorite massif. Mikhaylova, N.P., The magnetic rocks in the central Dnepr region.

7. Trudy Instituta Nefti AN KazSSR [Transactions of the Petroleum Institute of the Academy of Sciences of the Kazakhstan Academy of Sciences]: t. 2, Alma-Ata, 1958. 109 pp. From the contents: Dzhumagaliyev, T.N., The stratigraphy of the super-saline deposits in the Ural-Volga watershed. Grachev, R.I., Oil and gas prospects for the Ural-Volga watershed area.
8. Trudy Irkutskogo Gorno-Metallurgicheskogo Instituta [Transactions of the Irkutsk Mining and Metallurgical Institute]: Vyp. 14, Irkutsk, 1957, 137 pp. From the contents: Bol'shakov, P.M., The hydrogeology and water supply of the Kalanguysky region of the eastern Trans-Baykal area. Vasil'yeva, V.P., The stratigraphic problem of the Chuyskiy Muscovite deposits. Voropino, V.S., Basic features of the paleogeography of the Upper Cambrian in the Irkutsk cirque. Pleshanov, S.P., Data on the geology and mineral resources of the basin of the middle courses of the Oka River (Eastern Sayan). Zalutskiy, V.V., The problem of the origin of some veins of the granitoid rocks from Central Trans-Baykal. Sorokin, A.V., Pegmatites of the Western Baykal area.

## BIBLIOGRAPHY

Kosygin, M.K., Causes of reversed polarity in the magnetic anomaly of the Angara-Ilim iron deposits.

Trudy Chitinskogo Geologicheskogo Upravleniya [Transactions of the Chita Geological Administration]: Vyp. 1, Chita, 1957, 194 pp. Contents: Askasinskiy, V.V. and A.A. Demin, The geological service in the Trans-Baykal area during the 40 years of Soviet rule. Savadskiy, O.A. and A. Ye. Savadskaya, Brief review of the geophysical work in western Trans-Baykal. Krasnov, V.P., V.V. Starchenko and L.A. Taratuta, Study of the fundamental problems of geological structure. Kuznetsov, V.P., Precambrian stratigraphy in the Chita and western Amur areas. Starchenko, V.V., New data on the stratigraphy of the Mesozoic deposits in the southern part of central Trans-Baykal. Knyazev, G.I., The Argun area polymetallic belt. Sholkin, K.D. and L.N. Lenok, The Spassk polymetallic deposits. Kulgashhev, A.I., The geological structure of the Vozdvizhensk deposits. Pistsov, Yu. P., The Berezov iron ore deposits. Savadsky, O.A., Prospecting for polymetallic deposits in the Argun area using geochemical and geophysical methods.

Uchenyye Zapiski Tomskogo Universiteta [Scientific notes of Tomsk University]: t. 28, Tomsk, 1957, 173 pp. From the contents: Ivaniya, V.A., Devonian corals at Bely Kamen village on the Kara-Chumysh River (southwestern Kuzbass). Titova, Z.A., The terraces and recent tectonics of the Arguta Valley in the Altay. Ivanovsky, L.N., The Seventh Plenary Session of the Commission on the Study of the Quaternary Period held at Tomsk University.

### C. Books

### GEOLOGY

Akramkhodzhaev, A.M., and N.P. Petrov, K LITOLOGII MEZOZOYSKIKH OTLOZHENIY UZBEKISTANA [THE LITHOLOGY OF THE MESOZOIC DEPOSITS OF UZBEKISTAN]: Tashkent, Akademiya Nauk UzbekSSR, 1958, 184 pp.

Afanasyev, G.D., GEOLOGIYA MAGMATICHESKIKH KOMPLEKSOV SEVERNOGO KAVKAZA I OSNOVNYYE CHERTY SVYAZANNYY S NIMI MIN-

ERALIZATSII [GEOLOGY OF THE NORTH CAUCASUS MAGMATIC COMPLEXES AND BASIC FEATURES ASSOCIATED WITH THE ACCOMPANYING MINERALIZATION]: Tr. In-ta Geol. Rudn. Mestor., Petrogr., Min., i Geokhim., Akademiya Nauk SSSR, Vyp. 20, M., 1958, 138 pp.

3. Vlodavets, V.I., VULKANY I VULKANICHESKIYE OBRAZOVANIYA SEMYACHINSKOGO RAYONA [VOLCANOS AND VOLCANIC FORMATIONS OF THE SEMYACHINSK REGION]: Tr. Lab. Vulkanol. Akademiya Nauk SSSR, Vyp. 15, M., 1958, 192 pp.
4. GEOLOGIYA MESTOROZHDENIY REDKIKH ELEMENTOV, VYP 2, KOLUMBITONOSNYE GRANITY [GEOLOGY OF THE RARE-EARTH DEPOSITS; VOL. 2, COLUMBITE GRANITES]: M., Gosgeoltekhizdat, 1958, 48 pp.
5. Zaytsev, Yu. A., GERTSINSKAYA TEKTONICHESKAYA STRUKTURA ZAPADNOY CHASTI SARYSU-TENIZSKOGO VODORAZDELA I ULUTAU (TSENTRAL'NYY KAZAKHSTAN) [HERCYNIAN TECTONIC STRUCTURE OF THE WESTERN PART OF THE SARYSU-TENIZ WATERSHED AND ULUTAU (CENTRAL KAZAKHSTAN)]: Avtoref. dis. k. g.-m. n., M., 1958, 21 pp.
6. INSTRUKTSIYA PO RADIOMETRICHEskim LABORATORNYYM RABOTAM [INSTRUCTIONS IN RADIOMETRIC LABORATORY TECHNIQUES]: M. Gosgeoltekhizdat, 1958, 38 pp.
7. Klyushnikov, M.N., STRATIGRAFIYA I FAUNA NIZHNETRETIKHNYKH OTLOZHENIY UKRAINY [THE STRATIGRAPHY AND FAUNA OF THE LOWER TERTIARY DEPOSITS IN THE UKRAINE]: Kiev, Akademiya Nauk UkrSSR, 1958, 546 pp.
8. Levorsen, A.I., GEOLOGIYA NEFTI [PETROLEUM GEOLOGY]: M., Gostoptekhizdat, 1958, 486 pp.
9. Mazurov, N.N., S"YEMKA V MASSH-TABE 1:500 [SURVEYING ON THE SCALE OF 1:500]: Uch. Posobiye po Geodezii. Sverdlovsk, 1958, 91 pp.
10. Martynova, M.V., STRATIGRAFIYA I BRAKHIPODY FAMENSKOGO YARUSA ZAPADNOY CHASTI TSENTRAL'NOGO KAZAKHSTANA [THE STRATIGRAPHY AND BRACHIOPODS OF THE FAMENIAN STAGE IN THE WESTERN PART OF CENTRAL KAZAKHSTAN]: Aftoref. dis. k. g.-m. n. M., 1958,

13 pp.

11. Mirkamalova, S. Kh., STRATIGRAFIYA I FAUNA MOLLYUSKOV PALEOGEN-OVYKH OTLOZHENIY PRITASHKENT-SKOGO RAYONA I KYZYL-KUMOV [THE STRATIGRAPHY AND MOLLUSK FAUNA OF THE PALEOGENE FORMATIONS IN THE TASHKENT REGION AND KYZYL-KUMI]: M., Gosgeoltek-hizdat, 1958, 127 pp.
12. Potapov, I. I., APSHERONSKAYA NEFTE-NOSNAYA OBLAST' (GEOLOGICHE-SKAYA KHARAKTERISTIKA) [THE APSHERON OIL AREA (GEOLOGICAL CHARACTERISTICS)]: Baku, Akademiya Nauk Azerb. SSR, 1954, 538 pp.
13. PROIZVODITEL'NYYE SILY KOMI ASSR, T. 1. GEOLOGICHESKOYE STROYE-NIYE I POLEZNYYE ISKOPAYEMYYE [THE INDUSTRIAL POWER OF THE KOMI ASSR, VOL. 1, GEOLOGICAL STRUCTURE AND MINERAL RE-SOURCES]: Akademiya Nauk SSSR, 1953, 463 pp.
14. SOOBSHCHENIYA O RABOTAKH MEZH-DUVEDOMSTVENNOY POSTOYANNOY KOMISSII PO ZHELEZU AN SSSR [CONFERENCE ON THE WORK OF THE INTERDEPARTMENTAL PERMA-NENT COMMISSION ON IRON OF THE ACADEMY OF SCIENCE OF THE U.S.S.R.]: Vyp. 1, 117 pp., Vyp. 2, 24 pp., Vyp. 3, 70 pp., M., 1957-1958.
15. Stepanov, D. L., PRINTSIPIY I METODY BIOSTRATIGRAFICHESKIKH ISSLE-DOVANIY [PRINCIPLES AND METHODS OF BIO-STRATIGRAPHICAL INVESTI-GATIONS]: Tr. VNIGRI, Vyp. 113, L., Gostoptekhizdat, 1958, 180 pp.
16. Tatevosyan, L. K., GLUBINNOYE STRO-YENIYE ZEMNOY KORY ZAKAVKAZ'-YA PO DANNYM GRAVIMETRII [THE PLUTONIC STRUCTURE OF THE EARTH'S CRUST IN THE TRANS-CAUCASUS AREA, FROM GRAVI-METRIC DATA]: Avtoref. dis. k. g.-m. n. M., 1958, 12 pp.
17. TEZISY DOKLADOV GEOL. FAK. PERMSK. UN-TA NA OTCHETNOY NAUCH. KONF. 6-10 YANVARYA 1958 G. [THESIS REPORTS OF THE GEOLOGICAL FAKULTET OF PERM UNIVERSITY IN THE REPORTS OF THE SCIENTIFIC CONFERENCE OF JANUARY 6-10, 1958]: Perm', 1957, 41 pp.
18. Terekhin, Ye. I., RAZRABOTKA TEORII INTERPRETATSIY ELEKTRICHESKIKH ZONDIROVANIY, VYPOLNENNYKH NA-MORE [DEVELOPMENT OF A THEOR-Y FOR INTERPRETATION OF ELECTRI-CAL SOUNDING AS APPLIED TO MARINE WORK]: Aftoref. dis. k. g.-m. n. M., 1958, 10 pp.
19. TRUDY MEZH-DUVEDOMSTVENNOGO SOVESHCHANIYA PO RAZRABOTKE UNIFITSIROVANNYKH STRATIGRA-FICHESKIKH SKHEM SIBIRI 1956. DOKLADY PO STRATIGRAFIY DOKEM-BRYSKIKH OTLOZHENIY [PROCEED-INGS OF THE INTERDEPARTMENTAL CONFERENCE ON THE DEVELOP-MENT OF A UNIFIED STRATIGRAPH-IC SEQUENCE FOR SIBERIA, 1956. REPORTS ON THE STRATIGRAPHY OF PRECAMBRIAN FORMATIONS]: M. - L., Akademiya Nauk SSSR, 1958, 253 pp.
20. Fersman, A. Ye., IZBRANNYYE TRUDY [COLLECTED WORKS]: Vol. 4, M., Akademiya Nauk SSSR, 1958, 588 pp.
21. Florovskaya, V. N., LYUMINESTSENTNOY BITUMINOLOGICHESKIY METOD V NEFTYANNOY GEOLOGII [THE LUMI-NESCENT-BITUMINOLOGICAL METHOD IN PETROLEUM GEOLOGY]: M., 1957, 290 pp.
22. Khomentovskiy, V. V., GEOLOGICHE-SKOYE STROYENIYE I ISTONIYA RAZVITIYA VOSTOCHNO-URAL'-SKOGO ANTIKLINORIYA NA SRED-NEM URAL'E [THE GEOLOGICAL STRUCTURE AND HISTORY OF THE DEVELOPMENT OF THE EASTERN URAL ANTICLINORIUM IN THE CENTRAL URALS]: Tr. Geol. In-ta Akademiya Nauk SSSR, No. 7, M., 1958, 68 pp.
23. IV MEZHDUNARODNYY NEFTYANNOY KONGRESS, T. 10 DOPOLNENIYA I DISKUSSII [FOURTH INTERNATIONAL PETROLEUM CONGRESS, VOL. 10, SUPPLEMENTS AND DISCUSSIONS]: M., Gostoptekhizdat, 1958, 475 pp.
24. Shilov, V. N., KAYNOZOYSKIY VULKAN-IZM I KAYNOZOYSKIYE VULKANO-GENNYYE FORMATSII ZAPADNOY CHASTI YUZHNOGO SAKHALINA [CENOZOIC VULCANISM AND THE CENOZOIC VOLCANIC FORMATIONS OF THE WESTERN PART OF SOUTH-ERN SAKHALIN]: Avtoref. dis. k. g.-m. n. Yuzhno-Sakhalinsk, 1958, 20 pp.
25. Shurkin, K. A., GEOLOGICHESKIY

# BIBLIOGRAPHY

- OCHERK PITKYARANTSKOGO POLYA KERAMICHESKIKH PEGMATITOV (SEVERO-VOSTOCHNOYE PRILADOZH'YE) [GEOLOGICAL OUTLINE OF THE PITKYARANTSKIY FIELD CERAMIC PEGMATITES (NORTHEASTERN LADOGA REGION)]: M. -L., Akademiya Nauk SSSR, 1958, 87 pp.
6. Yakhimovich, V.L., KAYNOZOY BASHKIRSKOGO PREDURAL'YA, T. 2, CH. 1. CHETVERTICHNYYE OTLOZHENIYA NIZKIKH TERRAS REK BASHKIRSKOGO PREDURAL'YA [THE CENOZOIC OF THE BASHKIR URAL AREA, VOL. 2, PART 1. QUATERNARY DEPOSITS OF THE LOW TERRACES ON THE BASHKIR URAL RIVERS]: (Stratigrafiya), Ufa, 1957, 57 pp.
7. Barczyk, W. O., O UTWORACH GORNO-KREDOWYCH NA BONARCE POD KRAKOWEM. STUDIA SOC. SCI. TORUNENSIS, v. 3, N 2. Torun, 1956, 26 pp.
8. Braddock, W. A., STRATIGRAPHIC AND STRUCTURAL CONTROLS OF URANIAN DEPOSITS ON LONG MOUNTAIN, SOUTH DAKOTA: U.S. Geol. surv. Bull. 1063 -- A. Washington, 1957, 11 pp.
9. Buge, E., LES BRYOZOAIRE DU NEOGENE DE L'OUEST DE LA FRANCE ET LEUR SIGNIFICATION STRATIGRAPHIQUE ET PALEOBIOLOGIQUE: Mem. Museum nation. hist. natur., Ser. C, t. 6, Paris, 1957, 436 pp.
10. Crettaz, P., GEOLOGISCHE UNTERSUCHUNGEN AN DER ALPEN-APENNINERENZE IN LIGURIEN: (Italien), Zurich, 1955, 140 pp.
11. Crouzel, F., LE MIOCENE CONTINENTAL DU BASSIN D'AQUITAINE: Bull. Serv. carte geol. France, N 248, t. 54, Paris-Liege, 1957, 264 pp.
12. Dixey, F., COLONIAL GEOLOGICAL SURVEYS, 1947-56: Colon. geol. and mineral res. Bull. suppl. N 2, London, 1957, 129 pp.
13. Donner, J.J. and R.G. West, THE QUATERNARY GEOLOGY OF BRAGENSET, NORDAUSTLANDET, SPITSBERGEN. Norsk Polarinst. Skr. N 109, Oslo, 1957, 29 pp.
14. Drake, A.A. Jr., GEOLOGY OF THE WOOD AND EAST CALHOUN MINES CENTRAL CITY DISTRICT GILPIN COUNTY, COLORADO: U.S. Geol. surv. Bull. 1032-C, Washington, 1957, pp. 129-170.
35. Eden, R.A., I.P. Stevenson and W. Edwards, GEOLOGY OF THE COUNTRY AROUND SHEFFIELD: London, 1957, 238 pp.
36. THE GOLD PAN AS A QUANTITATIVE GEOLOGIC TOOL: U.S. Geol. surv. Bull. 1071-A, Washington, 1957, 54 pp.
37. Gonzalez-Reyna, J., MEMORIA GEOLOGICO-MINERA DEL ESTADO DE CHIHUAHUA (MINERALES METALICOS): Mexico, 1956, 280 pp.
38. Guild, P.W., GEOLOGY AND MINERAL RESOURCES OF THE CONGONHAS DISTRICT MINAS GERAIS, BRAZIL: U.S. Geol. surv. Prof. paper 290, Washington, 1957, 90 pp.
39. Hjelmqvist, S., ON THE OCCURRENCE OF IGNIMBRITE IN THE PRE-CAMBRIAN: Sver. geol. undertok., Ser. C, N 542, Stockholm, 1956, 12 pp.
40. Klepper, M.R. and D.G. Wyant, NOTES ON THE GEOLOGY OF URANIUM: U.S. Geol. survey Bull. 1046-F, Washington, 1957, pp. 87-148.
41. Macdonald, G.A. and J.P. Eaton, HAWAIIAN VOLCANOES DURING 1954: U.S. Geol. surv. Bull. 1061-B, Washington, 1957, pp. 17-72.
42. Melin, R.E., SELECTED ANNOTATED BIBLIOGRAPHY OF THE GEOLOGY OF SANDSTONE TYPE URANIUM DEPOSITS IN THE UNITED STATES: U.S. Geol. surv. Bull. 1059-C, Washington, 1957, pp. 59-175.
43. Neuman, R.B., MIDDLE ORDOVICIAN ROCKS OF THE TELLICO-SEVIER BELT EASTERN TENNESSEE: U.S. Geol. surv. Prof. paper 274-F, Washington, 1955, IV, pp. 141-178.
44. Raitt, R.W., SEISMIC-REFRACTION STUDIES OF ENIWETOK ATOLL: U.S. Geol. surv. Prof. paper 260-S, Washington, 1957, pp. 685-698.
45. REPORTS AND MAPS OF THE GEOLOGICAL SURVEY RELEASED ONLY IN THE OPEN FILES, 1956: U.S. Geol. surv. Circ. 401, Washington, 1957, 12 pp.
46. Reynolds, M.A. and J.G. Best, THE TULUMAN VOLCANO, ST. ANDREW STRAIT, ADMIRALTY ISLANDS: Commonw. Australia, Bureau min.

res., geol. and geophys. Rep. N 33, 1957, 38 pp.

47. Rosset, J., DESCRIPTION GEOLOGIQUE DE LA CHAÎNE DES ARAVIS ENTRE CLUSES ET LE COL DES ARAVAS (HAUTE-SAVOIE): Bull. Serv. carte geol. France, N 247, t. 53, Paris Liege, 1957, 147 pp.

48. Routhier, P., ETUDE GEOLOGIQUE DE LA BALAGNE SEDIMENTAIRE: Bull. Serv. carte geol. France N 249, t. 56, Paris-Liege, 1957, 29 pp.

49. Snel, M.J., ETUDE DES FORMATIONS DE TRAVERTINS CALCAIRES DANS LA PROVINCE DU KIVU: Serv. geol. Congo Belge, Bull. N 7, fasc. 1, 1956, 31 pp.

50. Terry, R.A., A GEOLOGICAL RECONNAISSANCE OF PANAMA: Occas. papers California Acad. sci. N 23, San Francisco, 1956, 91 pp.

51. Wilson, D., W.J. Sando and P.W. Kopf, GEOLOGIC NAMES OF NORTH AMERICA INTRODUCED IN 1936-1955: U.S. Geol. surv. Bull. 1056-A, Washington, 1957, 504 pp.

# PALEONTOLOGY

1. Dobrolyubova, T.A., NIZHNEKAMEN-NOUGOL'NYYE KOLONIAL'NYYE CHETYREKHLUCHEVYYE KORALLY RUSSKOY PLATFORMY [LOWER CARBONIFEROUS COLONIES OF TETRA CORALS ON THE RUSSIAN PLATFORM]: Tr. Paleontol. In-ta Akademiyi Nauk SSSR, t. 70. M., 1958, 223 pp.

2. Makridin, V.P., BRAKHIOPODY YUR-SKIKH OTLOZHENIY RUSSKOY PLATFORMY I NEKOTORYKH PRILEZHASH-CHIKH K NEY OBLASTEY [BRACHIOPODS OF THE JURASSIC DEPOSITS OF THE RUSSIAN PLATFORM AND SOME OF THE ADJACENT REGIONS]: Avtoref. dis. d. g. -m. n. M., 1958, 33 pp.

3. Nevesskaya, L.A., CHETVERTICHNYYE MORSKIYE MOLLYUSKI TURKMENII [QUATERNARY MARINE MOLLUSKS OF TURKMEN]: Tr. Paleontol. In-ta Akademiyi Nauk SSSR, t. 65, M., 1958, 81 pp.

4. Saakyan-Gezalyan, N.A., FORAMINIFERY TRETICHNYKH OTLOZHENIY YERE-VANSKOGO BASSEYNA [FORAMINI-

FERA OF THE TERTIARY YEREVAN BASIN DEPOSITS]: Yerevan, 1957, 139 pp.

5. Axelrod, D.I., MIO-PLIOCENE FLORAS FROM WEST-CENTRAL NEVADA: Univ., California Publ. geol. sci., v. 33, California, 1956, 321 pp.

6. Bougneres, L. and W. Remv, MITTEIL-UNG UBER DIE SPORON VON ZYGOP-TERIS SP. ABHANDL. DEUTSCH: Akad. Wiss. Kl. Chemie, Geol. und Biol., Jg. 1957, N 4, Berlin, 1957, 8 pp.

7. Fleming, C.A., THE GENUS PECTEN IN NEW ZEALAND: N.Z. Geol. surv. Paleont. bull. 26, Wellington, 1957, 69 pp.

8. Flower, R.H. and C. Teichert, THE CEPHALOPOD ORDER DISCOSORIDA: Univ. Kansas Paleont. contribut. 21, Mollusca, Art. 6, 1957, 144 pp.

9. Civulescu, R., FLORA PLIOCENA DE LA CORNITEL, Monograf geol. si paleont. 3, Bucuresti, 1957, 149 pp.

10. Gordon, M. Jr., MISSISSIPPIAN CEPHA-LOPODS OF NORTHERN AND EAST-ERN ALASKA: U.S. Geol. surv. Prof. paper 283, Washington, 1957, 61 pp.

11. Greguss, P., EIN LIGNIT AUS DEM MIOZAN VON RIXHOFT UND EINIGE WICHTIGE BEOBSACHTUNGEN AN EINEM "KNORRIA": Stamm. Abhandl. Deutsch. Akad. Wiss. Kl. Chemie, Geol., und Biol. Jg., 1957, N 3, Berlin, 1957, 16 pp.

12. Leclercq, S., ETUDE D'UNE FRUCTI-FICATION DE SPHENOPSIDE A STRUC-TURE CONSERVEE DU DEVONIEN SUPERIEUR: Mem. Acad. Roy., Bel-gique, t. 14, fasc. 3, Bruxelles, 1957, 39 pp.

13. MacNeil, F.S., CENEZOIC MEGA-FOSSILS OF NORTHERN ALASKA, U.S. Geol. surf. Prof. paper 294-C, Washington, 1957, pp. 99-126

14. Marwick, J., NEW ZEALAND GENERA OF TURRITELLIDAE, AND THE SPECIES OF STIRACOLPUS: N.Z. Geol. surv. Paleont. bull. 27, Wellington, 1957, 55 pp.

15. Meszaros, N., FAUNA DE MOLUSTE A DEPOZITELOR PALEOGENE DIN NORD-VESTUL TRANSILVANIEI: Monograf. geol. si paleont. I Bucu-resti, 1957, 174 pp.

# BIBLIOGRAPHY

- Peck, R.E., NORTH AMERICAN MESOZOIC CHAROPHYTA: U.S. Geol. surv. Prof. paper 294-A, Washington, 1957, 44 pp.
- Srodon, A. and M. Golabowa, *PLEJSTOCENSKA FLORA Z BEDLNA*: Warszawa, 1956, Ott. Inst. geol. Biul. 100 z badan czwartorzedu w Polsce t. 7.
- Thompson, M.L., *AMERICAN WOLFCAMPIAN FUSULINIDS*: Univ. Kansas, Paleont. contribut. 14, Protozoa, Art. 5, 1954, 225 pp.
- PETROGRAPHY, MINERALOGY, CRYSTALLOGRAPHY, GEOCHEMISTRY
- Apel'tsin, F.R., *MALYYE INTRUZII ZOLOTONOSNYKH POLEY GLAVNOGO ZOLOTONOSNOGO POYASA SEVEROVOSTOKA SSSR* [SMALL GOLDBEARING INTRUSIONS IN THE MAIN GOLD BELT OF NORTHEASTERN USSR]: Aftoref. dis. d. g.-m. n. Magadan, 1958, 43 pp.
- Bel'kevich, P.I., A.I. Verzal and L.I. Tkachev, *SPEKTROFOTOMETRICHE-SKOYE I ELEKTRONNO-MIKROSKOPICHESKOYE ISSLEDOVANIYA GLIN* [SPECTRO-PHOTOMETRIC AND ELECTRON MICROSCOPE STUDIES OF CLAYS]: Minsk. 1958, 14 pp.
- Vasil'yeva, Z.V., *IZOMORFNYYE ZAMESHCHENIYA V APATITAKH IZ RAZLICHNYKH MESTOROZHDENIY SOYUZA* [ISOMORPHOUS REPLACEMENT IN APATITES FROM VARIOUS DEPOSITS IN THE U.S.S.R.]: Avtoref. dis. k. g.-m. n. M., 1958, 15 pp.
- Vasil'chenko, S.F., *VZAIMOOTNOSHENIYA ZOLOTORUDNYKH ZHIL I GRANITIZIROVANNYKH VMESHCHAYUSHCHIKH POROD NA KAZAKOVSKOM MESTOROZHDENII* [THE RELATIONSHIP BETWEEN GOLDBEARING VEINS AND ASSOCIATED GRANITIZED ROCKS IN THE KAZAK DEPOSIT]: Avtoref. dis. k. g.-m. n. M., 1958, 13 pp.
- Zabavnikova, N.I., *IZOMORFNYYE ZAMESHCHENIYA V SFENAKH RAZLICHNYKH MESTOROZHDENIY SOVETSKOGO SOYUZA* [ISOMORPHOUS REPLACEMENT OF SPHENE IN VARIOUS DEPOSITS IN THE SOVIET UNION]: Avtoref. dis. k. g.-m. n. 1958, 15 pp.
- ISSLEDOVANIYA I ISPOL'ZOVANIYA GLIN. MATERIALY SOVESHCH. VO L'VOVE V MAYE-IYUNE 1957G [THE STUDY AND USES OF CLAYS. PROCEEDINGS OF A CONFERENCE IN L'VOV, MAY-JUNE 1957]: L'vov, L'vovsk. Un-t, 1958, 856 pp.
- Karyukina, V.N., *INSTRUKTSIYA POL'ZOVANIYA I OPISANIYE LABORATORII PO OPREDELENIYU pH SUSPENZIY MINERALOV* [INSTRUCTIONS IN THE USE AND LABORATORY DESCRIPTION pH DETERMINATIONS OF MINERAL SUSPENSIONS]: M., 1958, 11 pp.
- Kokshenev, B.G., *OPREDELENIYE TEPLOPROVODNOSTI GORNYKH POROD* [DETERMINATION OF THERMAL CONDUCTIVITY IN ROCKS]: M., Ugletekhizdat, 1957, 17 pp.
- Lebedev, V.I., *OSNOVY ENERGETICHESKOGO ANALIZA GEOKHIMICHESKIKH PROTSESSOV* [THE BASIS OF THE ENERGY ANALYSIS OF GEOCHEMICAL PROCESSES]: L., Leningr. State Univ., 1957, 341 pp.
- Lukashev, K.I., *GEOKHIMICHESKIY PROTSESSY MIGRATSII I KONTSENTRATSII ELEMENTOV V BIOSFERE* [GEOCHEMICAL PROCESSES OF MIGRATION AND CONCENTRATION OF ELEMENTS IN THE BIOSPHERE]: Minsk, 1957, 218 pp.
- Malyuga, V.I., *PRIRODNYYE RAZNOVIDNOSTI PERVICHNYKH RUD ZIGAZINOKOMAROVSKIKH MESTOROZHDENIY I IKH STRATIGRAFICHESKOYE POLOZHENIYE* [NATURAL VARIETIES OF PRIMARY ORES IN THE ZIGAZINOKOMAROV DEPOSITS AND THEIR STRATIGRAPHIC POSITION]: Ufa, 1957, 36 pp.
- Marakushev, A.A., *SVYAZANNY S GRANITIZATSIYEV METASOMATIZM DOLOMITOVYKH MRAMOROV I KRISTALLOSLANTSEV NA TAYEZHNO M ZHELEZORUDNOM MESTOROZHDENII V ARKHEYE ALDANSKOY PLITY* [THE METASOMATISM OF THE DOLOMITE MARBLES AND CRYSTALLINES RELATED TO GRANITIZATION IN THE ARCHEAN TAYEZHNY IRON ORE DEPOSIT OF THE ALDAN BLOCK]: Magadan, 1958. Ott. Tr. Dal'nevost. Fil. Akademiya Nauk SSSR, Ser. Geol., t. 3, pp. 87-105.
- Muzafarov, V.G., *OPREDELITEL' MINERALOV I GORNYKH POROD* [LOCATOR OF MINERALS AND ROCKS]: Izd. 3-e M., Uchpedgiz, 1958, 172 pp.

14. Pavlov, P.V., KRISTALLICHESKAYA STRUKTURA GERDERITA, DATOLITA I GADOLINITA [CRYSTALLINE STRUCTURE OF HERDERITE, DATOLITE AND GADOLINITE]: Avtoref. dis. k. f.-m. n. M., 1958, 8 pp.
  15. RAZDELENIYE TSIRKONA I PIROKHLORA METODOM ELEKTRICHESKOY SEPARATSII [SEPARATION OF ZIRCON AND PYROCHLORE BY THE ELECTRIC METHOD]: Sverdlovsk, 1957, 21 pp.
  16. Tvalchrelidze, G.A., OSNOVNYYE CHERTI ENDOGENNOY METALLOGENII GRUZII [BASIC FEATURES OF ENDOGENIC METALLOGENY IN GEORGIA]: M., Gosgeoltekhizdat, 1958, 95 pp.
  17. U. Li-zhen', PETROLOGIYA NEFELINOVYKH POROD RAYONA KUKISVUMCHORRA I POACHVUMCHORRA SUBVULKANA Khibin (NA KOL'SKOM POLUOSTROVE) [PETROLOGY OF THE NEPHELINE ROCKS IN THE KUKISVUMCHORRA AND POACHVUMCHORRA REGION OF THE SUBVOLCANO, Khibin (KOLA PENINSULA)]: Aftoref. dis. k. g.-m. n. L., 1958, 24 pp.
  18. Usenko, I.S., OSNOVNYYE I UL'TRA-OSNOVNYYE GORNYYE PORODY BASSEYNA YUZHNOGO BUGA [BASIC AND ULTRA-BASIC ROCKS OF THE SOUTHERN BUG BASIN]: In-t Geol. Nauk Akademiya Nauk UkrSSR, Ser. Petrog., Min. i Geokhim., Vyp. 5, Kiev, 1958, 142 pp.
  19. Shchepochkina, N.I., FIZIKO-KHIMICHESKIYE ISSLEDOVANIYA TITANATOV BARIYA I ZHELEZA [PHYSICAL-CHEMICAL STUDIES OF BARIUM AND IRON TITANATES]: Tr. In-ta Geol. Rudn. Mestor., Petrogr., Min. i Geokhim., Vyp. 11, M., Akademiya Nauk SSSR, 1958, 61 pp.
  20. Allen, R.D., DIFFERENTIAL THERMAL ANALYSIS OF SELECTED BORATE MINERALS: U.S. Geol. surv. Bull. 1036-K, Washington, 1957, pp. 193-208.
  21. Armstrong, F.C. and P.L. Weis, URANIUM-BEARING MINERALS IN PLACER DEPOSITS OF THE RED RIVER VALLEY IDAHO COUNTY, IDAHO: U.S. Geol. surv. Bull. 1046-C, Washington, 1957, pp. 25-36.
  22. Botinelly, T. and A.D. Weeks, MINERALOGIC CLASSIFICATION OF URANIUM-VANADIUM DEPOSITS OF THE COLORADO PLATEAU: U.S. Geol. surv. Bull. 1074-A, Washington, 1957, 5 pp.
  23. Schmucker, U., GESTEINSMAGNETISCHE UNTERSUCHUNGEN UND EXPERIMENTE AM BASALT DES STEINBERGES BEI BARLISSEN: Abhandl. Akad. Wiss. Gottingen. Mathem-phys. Kl. 3-te Folge, N 26, Gottingen, 1957, 100 pp.
  24. Steven, T.A., METAMORPHISM AND THE ORIGIN OF GRANITIC ROCKS NORTHGATE DISTRICT, COLORADO: U.S. Geol. surv. Prof. paper 274-M, Washington, 1957, pp. 335-377.
  25. Van Tassel, R., DECOUVERTE DE CRANDALLITE EN BELGIQUE: Bull. Inst. roy. sci. natur., Belgique, t. 32, N 33, Bruxelles, 1956, 10 pp.
  26. \_\_\_\_\_, SIDERONATRITE DANS DES CHARBONNAGES BELGES: Bull. Inst. roy. sci. natur., Belgique, t. 32, N 51, Bruxelles, 1956, 4 pp.
  27. Tvřznik, B. and J. Havie, MINERALOGICKO-GEOLOGICKA BIBLIOGRAFIE CSR ZA ROK 1956: Praha, 1957, 173 pp.
- MINERAL RESOURCES, METHODS OF PROSPECTING AND LOCATION
1. Andreyev, P.S., O RAZVEDKE MESTOROZHDENIY POLEZNYKH ISKOPAYEMYKH (V PORYADKE OBSUCHDENIYA) [PROSPECTING FOR MINERAL RESOURCES (IN ORDER OF DISCUSSION)]: Tr. Dal'nevost. Politekh. In-ta, t. 48, Vyp. 6, 1958, 9 pp.
  2. ZAPASY UGLEY I GORYUCHIKH SLANTSEV SSSR. KRATKAYA SVODKA REZUL'TATOV PODSCHETA 1956 G. [COAL AND OIL SHALE RESOURCES OF THE U.S.S.R. A SHORT SUMMARY OF THE RESULTS OF THE 1956 ESTIMATE]: M., Gosgeoltekhizdat, 1958, 178 pp.
  3. Zikeyev, T.A., SPRAVOCHNIK PO KACHESTVU ISKOPAYEMYKH UGLEY I GORYUCHIKH SLANTSEV SOVETSKOGO SOYUZA [HANDBOOK ON THE QUALITY OF COAL AND OIL SHALES IN THE SOVIET UNION]: M., Ugletekhizdat, 1957, 144 pp.
  4. Knyazev, G.I., POISKOVO OTSENOCHNYE PRIZNAKI VYKHODOV POLIMETALLICHESKIKH MESTOROZH-

## BIBLIOGRAPHY

- DENIY VOSTOCHNOGO ZABAYKAL'YA [EXPLORATORY AND ESTIMATING CRITERIA TO DETERMINE THE YIELD OF POLYMETALLIC DEPOSITS IN THE EASTERN TRANS-BAYKAL AREA]: Chita, 1958, 134 pp.
- Narchemashvili, O.V., VERKHNEMELO-VYYE FOSFORITY GRUZII [THE UPPER CRETACEOUS PHOSPHORITES OF GEORGIA]: Avtoref. dis. k. g. -m. n. M., 1957, 15 pp.
- Chesnokov, M.M., RAZRABOTKA GRANITNYKH MESTOROZHDENIY [MINING OF GRANITE]: M., Akademiya Nauk SSSR, 1958, 142 pp.
- Yakubovich, A.L., TSINTILLYATSION-NAYA RADIOMETRICHESKAYA APPARATURA I VOZMOZHNOСТИ YEYE PRIMENENIYA DLYA GEOLOGICHESKIKH POISKOV I RAZVEDKI [SCINTILLATION RADIOMETRIC APPARATUS AND ITS USE FOR GEOLOGICAL EXPLORATION AND PROSPECTING]: M., Ugletekhizdat, 1958, 52 pp.
- Armstrong, F.C., DISMAL SWAMP PLACER DEPOSIT ELMORE COUNTY IDAHO: U.S. Geol. surv., Bull. 1042-K, Washington, 1957, pp. 383-392.
- Cannon, H.L., DESCRIPTION OF INDICATOR PLANTS AND METHODS OF BOTANICAL PROSPECTING FOR URANIUM DEPOSITS ON THE COLORADO PLATEAU: U.S. Geol. surv. Bull. 1030-M, Washington, 1957, pp. 399-516.
- CORE LOGS FROM SODA LAKE, SAN BERNARDINO COUNTY, CALIFORNIA: U.S. Geol. surv. Bull. 1045-C, Washington, 1957, pp. 81-96.
- Davis, R.E., MAGNESIUM RESOURCES OF THE UNITED STATES -- A GEOLOGIC SUMMARY AND ANNOTATED BIBLIOGRAPHY: U.S. Geol. surv. Bull. 1019-E, Washington, 1957, pp. 373-515.
- Hail, W.J., RECONNAISSANCE FOR URANIUM IN ASPHALT-BEARING ROCKS IN THE WESTERN UNITED STATES: U.S. Geol. surv. Bull. 1046-E, Washington, 1957, pp. 55-85.
- Johnson, H.S. Jr., URANIUM RESOURCES OF THE SAN RAFAEL DISTRICT, EMERY COUNTY, UTAH -- A REGIONAL SYNTHESIS: U.S. Geol. Surv. Bull. 1046-D, Washington, 1957, pp. 37-54.
14. Lang, W.L., ANNOTATED BIBLIOGRAPHY AND INDEX MAP OF SALT DEPOSITS IN THE UNITED STATES: U.S. Geol. surv. Bull. 1019-J, Washington, 1957, pp. 715-753.
15. Lawthers, R. and H.R. Mark, BIBLIOGRAPHY OF TITANIUM DEPOSITS OF THE WORLD: U.S. Geol. surv. Bull. 1019-G, Washington, 1957, pp. 543-608.
16. Parshall, E.E. and L.F. Rader, Jr., MODEL<sup>154</sup> TRANSMISSION AND REFLECTION FLUORIMETER FOR DETERMINATION OF URANIUM WITH ADAPTATION TO FIELD USE: U.S. Geol. surv. Bull. 1036-M, Washington, 1957, pp. 221-251.
17. Prucha, J.J., PYRITE DEPOSITS OF ST. LAWRENCE AND JEFFERSON COUNTIES, NEW YORK, N.Y.: St. Museum and Sci. serv. Bull. N 357, Albany, 1957, 87 pp.
18. Trumbell, J.V.A., COAL RESOURCES OF OKLAHOMA: U.S. Geol. surv. Bull. 1042-J, Washington, 1957, pp. 307-383.
19. Walker, R.T. and W.J. Walker, THE ORIGIN AND NATURE OF ORE DEPOSITS: Colorado, 1956, XIII, 384 pp.

## HYDROGEOLOGY, ENGINEERING GEOLOGY

1. Antonov, A.A., GIDROGEOLOGICHESKIYE USLOVIYA BURROUGHOL'NYKH MESTOROZHDENIY TSENTRAL'NOY CHASTI YUZHNOGO KRYLA PODMOSKOVNOGO BASSEYNA I IKH VLIYANIYE NA PROTSESS PODZEMNOY GAZIFIKATSII UGLYA [HYDROGEOLOGICAL CONDITIONS IN THE LIGNITE DEPOSITS OF THE CENTRAL PART OF THE SOUTHERN SIDE OF THE MOSCOW BASIN AND THEIR EFFECT ON THE UNDERGROUND GASIFICATION OF COAL]: Avtoref. dis. k. g. -m. n. M., 1958, 21 pp.
2. GIDROGEOLOGICHESKOYE RAYONIROVANIYE PODZEMNYKH VOD MOLDAVII TSELEY VODOSNABZHENIYA [HYDROGEOLOGICAL REGIONALIZATION OF GROUND WATER USED FOR WATER-SUPPLY PURPOSES IN MOLDAVIA]: Kishinev, 1958, 6 pp.
3. KONFERENTSIYA MLADSHIKH NAUCHNYKH SOTRUDNIKOV I ASPIRANTOV LABORATORII GIDROGEOLOGICHESKOGO

SKIKH PROBLEM AN SSSR [CONFERENCE OF THE JUNIOR SCIENTIFIC WORKERS AND ASPIRANTS OF THE LABORATORY ON HYDROGEOLOGICAL PROBLEMS, AKADEMIYA NAUK SSSR]: M., 1958, 34 pp.

4. Kuz'minov, M.P., ZEMLYANYYE GIDROTEKHNICHESKIYE SOORUZHENIYA [EARTHEN HYDROTECHNICAL CONSTRUCTION]: Tashkent, Akademiya Nauk UzSSR, 1958, 220 pp.
5. PONIZHENIYE UROVNYA GRUNTOVYKH VOD LEGKIMI IGLOFIL'TROVYMI USTANOVKAMI I EZHEKTORNYMI IGLOFIL'TRAMI (INSTRUKTSIYAPOSObIYE) [LOWERING OF THE WATER TABLE BY LIGHT "NEEDLE FILTRATION" APPARATUS AND "NEEDLE FILTRATION" EJECTOR PUMPS (INSTRUCTION - MANUAL)]: M., Gosstroyizdat, 1958, 109 pp.
6. REZOLYUTSIYA SOVESHCHANIYA KURORTNYKH INSTITUTOV PO VOPRO-
7. Khoroshavin, N.G., YODOBROMNYYE VODY PERMSKOY OBLASTI [IODINE-BROMINE WATERS OF THE PERM' REGION]: Perm', 1958, 62 pp.
8. MacKichan, K.A., ESTIMATED USE OF WATER IN THE UNITED STATES 1955: U.S. Geol. surv. Circ. 398, Washington, 1957, 18 pp.
9. MAGYÁRSZAG ASVANY -- ES GYOCY-VISEI: Budapest, Akad. Kiado, 1957, 963 pp.
10. Wolman, M.G., L. Leopold, B. RIVER FLOOD PLAINS: SOME OBSERVATIONS ON THEIR FORMATION: U.S. Geol. surv. Prof. paper 282-C, Washington, 1957, 87-109 pp.

SAM GIDROGEOLOGII MINERAL'NYKH VOD (27-30 YANVARYA 1958G.) [RESOLUTION OF THE HEALTH INSTITUTES ON PROBLEMS OF HYDROGEOLOGY AND MINERAL WATERS (JAN. 27-30, 1958)]: M., 1958, 7 pp.

## CHRONICLE

### General Meeting of the Department of Geologic and Geographic Sciences of the U. S. S. R. Academy of Sciences

At the General Meeting of the Department of Geologic and Geographic Sciences of the U. S. S. R. Academy of Sciences, held on June 1, 1958, Academy Member N. S. Shatskiy read a paper on "The Origin and Movements of the Earth's Crust;" V. V. Belousov, Corresponding Member of the U. S. S. R. Academy of Sciences, reported on his work in the field of tectonophysics in his paper entitled "Some Achievements and Prospects of Tectonophysics Research."

Both papers were received with great interest and were followed by a lively exchange of opinions. The papers will be published in the "Izvestiya, U. S. S. R. Academy of Sciences, Geologic Series."

Elections for corresponding members to the Geologic and Geographic Department of the Academy were held, and the following were unanimously elected:

1) Khabib Mukhamedovich Abdullayev, Doctor of Geologic and Mineralogic Sciences, and Chairman of the Academy of Sciences of the Uzbek S. S. R.

2) Aleksandr Vol'demarovich Peyve, Doctor of Geologic and Mineralogic Sciences, and Deputy Director of the Geologic Institute of the U. S. S. R. Academy of Sciences.

3) Professor Viktor Aleksandrovich Priklonskiy, Doctor of Geologic and Mineralogic Sciences, and Director of the Hydrogeologic Laboratory of the U. S. S. R. Academy of Sciences.

4) Vladimir Ivanovich Smirnov, Doctor of Geologic and Mineralogic Sciences, Professor at Moscow University.

5) Professor Veniamin Grigor'yevich Bogorov, Doctor of Biologic Sciences, and Deputy Director of the Oceanography Institute of the U. S. S. R. Academy of Sciences.

6) Professor Ivan Stepanovich Isakov, Admiral of the Fleet.

